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Potential Environmental Effects of an Offshore Submerged Nuclear Power Plant,

Volume 1

330

ENVIRONMENTAL PROTECTION AGENCY • WATER QUALITY OFFICE

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Potential environmental effects of wastes from an 1190-Mwe pressurized-water nuclear power plant, submerged 250-ft deep at four representative sites off the U.S. mainland, were studied. The thermal field of the plant's cooling water discharge, and the distribution of radionuclides in the sea, were analyzed. In every case, the thermal "mixing zone" (by the most stringent present standards) was found to end before either a surface or subsurface field was established, and to be much smaller than for a plant in shallower waters. Fewer organisms would be killed by entrainment in the cooling water than at a coastal plant. A "batch" release of radionuclides, after the hypothetical nuclear accident, would harm life, requiring suspension, of local fishing for about 10 weeks. No potential ecological damage was predictable from the ordinary minute release of radionuclides, the thermal discharge, or other wastes. Volume I presents the rationale, analyses and results of the complete study. (See also W72-06615).
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POTENTIAL ENVIRONMENTAL EFFECTS OF AN OFFSHORE SUBMERGED NUCLEAR POWER PLANT

VOLUME 1

by

GENERAL DYNAMICS
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Groton, Connecticut, 06340

for the

WATER QUALITY RESEARCH OFFICE
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ABSTRACT

Potential environmental effects of wastes from an 1190-Mwe pressurized-water nuclear power plant, submerged 250-ft deep at four representative sites off the U.S. mainland, were studied. The thermal field of the plant's cooling water discharge, and the distribution of radionuclides in the sea, were analyzed. In every case, the thermal "mixing zone" (by the most stringent present standards) was found to end before either a surface or subsurface field was established, and to be much smaller than for a plant in shallower waters. Fewer organisms would be killed by entrainment in the cooling water than at a coastal plant. A "batch" release of radionuclides, after the worst hypothetical nuclear accident, would harm life, requiring suspension of local fishing for about 10 weeks. No potential ecological damage was predictable from the ordinary minute release of radionuclides, the thermal discharge, or other wastes.

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Note on Organization: Volume 1 presents the rationale, analyses, and results of the complete study. Volume 2 is a descriptive treatise and collation of data on the representative offshore sites, which forms the basis for application of the analytical models to those sites, and for the assessment of the effects of power plant wastes on the marine biota.

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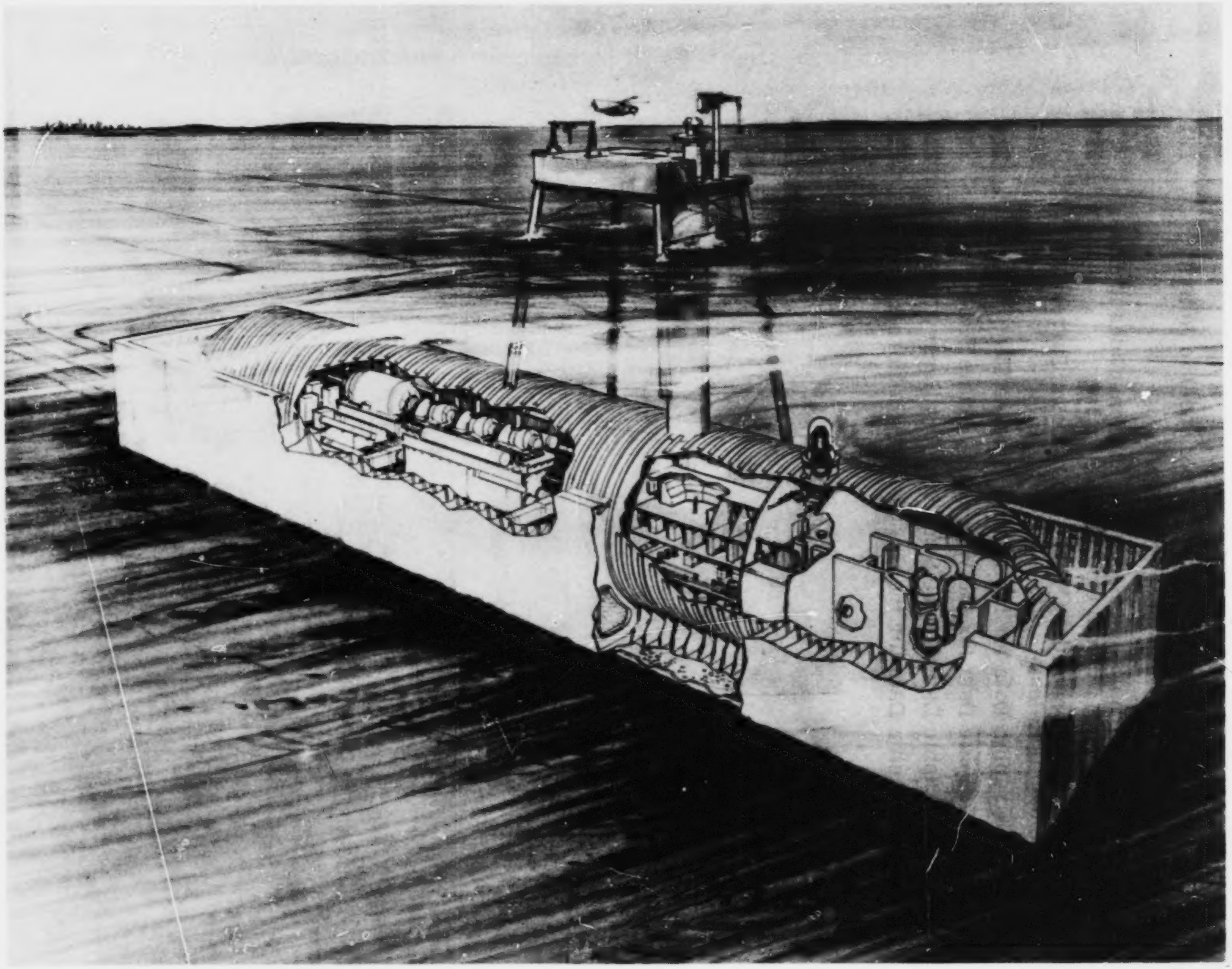

Frontispiece. Artist's Rendering of 1190-Mwe Submerged Offshore Power Station

Section 1
CONCLUSIONS

The menace to the ecological balance in coastal, estuarine, and inland waters produced by the rapid increase in power-generating capacity has been widely recognized. An alternative to present practice has been considered, in which a nuclear power plant is submerged offshore in waters about 250-ft deep (see frontispiece, opposite). The studies for this report were made to ascertain whether or not such a power plant would have discernible effects on life in continental shelf waters at several representative sites off the U.S. mainland. The studies were based on a pressurized-water reactor plant having characteristics typical of large commercial nuclear plants in operation today. "Worst case" conditions were commonly used in the analyses. For instance, thermal fields were predicted for a single discharge without optimization. No attempt was made to improve the thermal field by varying design parameters such as flow conditions or discharge geometry. The radionuclide analyses include compounded conservatisms, such as the assumptions that the concentrations of all radionuclides in the reactor plant's primary coolant water would reach their core cycle maxima simultaneously, that these concentrations would persist over a full year, and that the radionuclides released to the condenser cooling water would be diluted in only a fraction of the available flow. No consideration was given in site selection to seek locales where the power plant would be less likely to have detrimental effects. For these reasons, the conclusions drawn from the results are considered to be conservative. The principal conclusions are:

1. From the data reviewed and the theoretical analyses made, ecological damage from the normal operation of a large nuclear power plant appears to be unlikely at any of the sites considered.
2. In every case, the thermal "mixing zone," as defined by the most stringent standards presently applied to coastal installations, ends before either a surface or subsurface field is established. This is an important finding, because any surface field that might result will be at a temperature that is acceptable under these standards. Typical values were chosen for the condenser operating condition and discharge design. For any given deep water site, these variables could be

manipulated to give an improved thermal field. Moreover, any possibility of recirculating the condenser cooling water can be precluded.

3. Analysis indicates that the discharge of heated waters at depth results in a mixing zone that is considerably smaller than that which results in shallow water -- about 5 percent of the volume in a typical instance.

4. Total radioactivity added by the power plant to the condenser discharge waters at the point of discharge, based on very cautious assumptions, would be at most just half that of the naturally occurring potassium-40 activity in the sea, and this would be rapidly reduced by dilution in sea water and radioactive decay.

5. A major nuclear accident of the worst sort that can be hypothesized (i.e., breach of containment, an accident that has not occurred in any nuclear power plant to date), would harm marine biota in the area of the plant, and the effects might linger for about 10 weeks after the accident. Suspension of fishing activities could minimize the hazard to man. Calculations of radionuclide concentrations and specific activities after an accident, related to "maximum permissible" standards, and based on extremely conservative assumptions, indicate a very low probability of any ultimate damage to man after a major nuclear accident.

6. At the representative sites considered, nonthermal, nonradioactive liquid wastes such as sewage would have inconsequential effects, even if discharged to sea in an essentially untreated condition. Economical and effective treatment systems are available, moreover, for plants at sites where they might be advantageous.

7. Since phytoplankton population densities vary with light intensity, at a depth of 250-ft few phytoplankton ordinarily would be entrained in the cooling water, except possibly in very clear water where the eutrophic zone is deep, as off the eastern coast of Florida. Of the phytoplankton present and entrained in the cooling water at these depths, few would experience temperatures in excess of their known thermal tolerances, and depletion of the phytoplankton population

seems improbable. Review of the literature on thermal tolerances and effects of hydrodynamic buffeting, leads to the judgment the juvenile fish and fish eggs should suffer little damage in passage through the condensers, and that fish acclimated to the thermal plume will not experience severe cold shock if the plant is shut down. Sufficient knowledge apparently exists to keep entrainment of adult fish at inconsequential levels, by appropriate design of the cooling water intakes. Higher plants and attached algae do not occur at the depths considered.

8. Some larval and adult holoplanktonic zooplankton and meroplanktonic forms of benthic organisms will be killed by entrainment. Fewer species of the latter will be entrained than at a coastal power plant, since the populations will be less dense. Some larval fish immediate to the plant might suffer heavy mortality seasonally, as spawned eggs hatch.

9. Phytoplanktonic and zooplanktonic diversity indices should remain unchanged at all of the sites considered, because the waste heat will be rapidly dissipated, and the assortment of diverse and very widely distributed species prevalent over the continental shelf will be continuously renewed by water transport.

Section 2
RECOMMENDATIONS

1. In order to minimize thermal pollution of coastal, estuarine, and inland waterways, and the potential effects of a major nuclear accident, more consideration should be given to the construction of nuclear power plants offshore, in relatively deep continental shelf waters.
2. In addition to potential effects, and the economics and technical development of offshore siting, questions such as property rights, regulatory jurisdiction, fiscal policy, nuclear indemnification, fishing and navigation privileges, etc., should be examined by the appropriate government agencies and the legislature.
3. Between the shore-based plant and the completely submerged plant, there are many compromises in which some or most of the principal ecological advantages of the deep-water plant might be realized at lower capital cost. Hence, consideration should be given to studies of potential effects of power plants in waters shallower and closer to shore than in this report.
4. Studies should also be undertaken of the environmental implications of nonnuclear power plants offshore.
5. Specific research programs, such as described in section 9 of this report, are recommended as well, to close some of the gaps in present knowledge and techniques. This would permit more thorough evaluation of offshore power plant siting.

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Section 3
INTRODUCTION

The purpose of this study was to predict the potential effect of thermal and radioactive wastes from an offshore, submerged, nuclear power-generating station on its environs. The power station was considered as situated in waters about 250-ft deep at several representative sites on the Atlantic and Pacific coasts of the United States. The frontispiece shows the general concept on which the study was predicated. This plant has a pressurized water reactor with a net electrical output of about 1190 Mw(e). The concept entails shipyard construction of the whole plant, and its subsequent emplacement on the seabed. It would be manned through an access trunk to a platform above the sea's surface. Studies had been made of the general arrangement and structural characteristics, hydrostatics and ballasting, construction feasibility and schedule, transmission of power to shore by submarine cables, feasibility of emplacement, and market demand and economics. This previous work had shown the concept to be technically feasible, economically competitive with plants of similar size on land (Marble et al, 1970), and it was believed that the probability of detrimental effects on the environment would be smaller than for a similar power plant on land. Extrapolation of curves showing growth in demand for power, figure 1, with the influence of

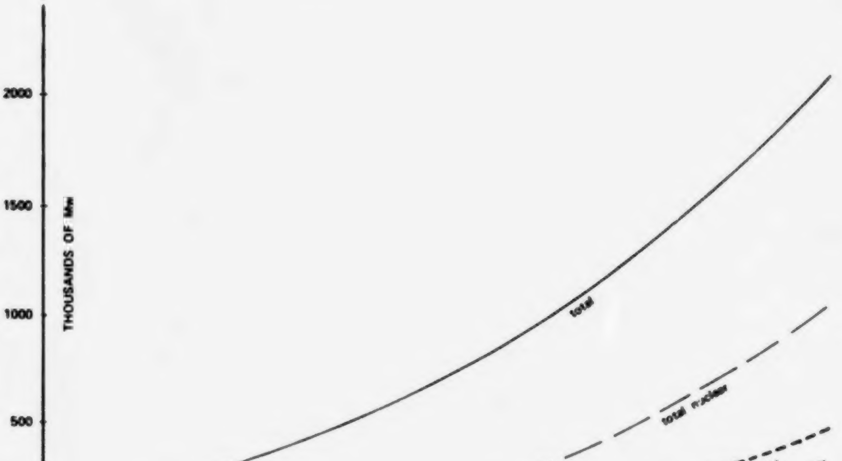

Figure 1. Projected U.S. Requirements for Power-generating Capacity

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the increasing concern for environmental quality, had indicated a large potential demand for such stations by the 1980s. Cautious projections of demand for electricity had shown that over the next 20 years, 1-million megawatts of new generating capacity would be required, and that over half of that growth would be nuclear. That is, the equivalent of about 500 nuclear power-generating stations of 1000 Mw(e) each (an average size for large baseload central stations projected for construction over the next few years) will have to be designed and built if the country's energy needs are to be met. Figure 2, which shows the distribution today of demand for electricity on the east and west coasts, indicates that a considerable portion of this growth might be met by offshore generating stations.

Among the principal motives for development of the offshore power plant concept had been recognition of:

1. The detrimental effects of waste heat discharge on inland and estuarine waters caused by the exponential growth in demand for electricity.

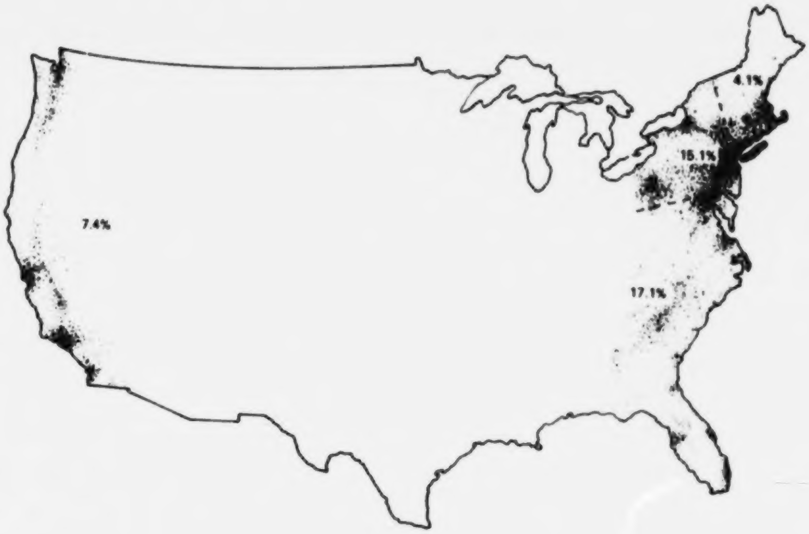

Figure 2. Current Production of Electricity on the U.S. East and West Coasts as a Percentage of National Total (Stipling Indicates Population Density)

2. The rapidly mounting difficulties confronting the utilities in finding sites for power plants on land.

It was felt that a power plant offshore in deeper water would overcome the first of these impediments by using the immense heat sink of the open sea for heat rejection by its condensers. Heat rejection offshore in 250 ft of water had also been expected to disturb life less than heat rejection near or on shore: biota of the littoral zone typically are restricted to narrow areas when compared with those that favor the open shelf; they frequently are exposed to temperatures near the upper limit of their tolerance; and generally poorer circulation of new water is found as the physiographic boundaries constrict. If a littoral zone were altered, the biota in it might not have areas adjacent with temperatures and salinity conditions suitable for survival. Offshore at depth it was thought, prevailing temperatures would be more constant, biological populations would be typically less dense and scattered over larger areas, and the flushing rates would be usually greater and more consistent. Thus, the general opinion was that great numbers of such power plants might be built without measurable thermal damage to even small portions of the environment, but this remained to be shown. Among the conditions foreseen that might interfere with the dispersal of heat or cause other troubles were:

1. Stratification of the water column which might retard convection.
2. Weak currents, which even if only seasonal or intermittent, might allow the general temperature to rise to unacceptable levels.
3. Sediment instability, siltation, or scouring on certain bottoms, which might make them unacceptable as sites.
4. Extended periods of onshore winds which might cause warm surface waters to accumulate inshore.

The safety of offshore nuclear plants, as concerns radioactive hazards to population centers, has been considered in other studies. One of these was done by the Oak Ridge National Laboratory of the AEC, for a boiling water reactor housed in a concrete caisson below sea level and surrounded by an artificial island. It concluded that such a plant might be slightly more expensive than one with a conventional reactor containment, but that there would be substantial safety advantages:

> "3. Underwater containment of water-cooled reactors should provide improved post-accident retention of fission products. This comes about because (a) the external sea pressure opposes out-leakage of fission products . . . and (c) the sea pressure furnishes continuous leak testing of the outer containment barrier.
>
> "4. Underwater containment systems provide more reliable decay heat removal following a reactor accident, since heat can be removed by a continuously operating natural circulation heat exchanger without electrical power, moving equipment, or other mechanical action.
>
> "5. Accidental flooding of the caisson with seawater would result in an economic loss; however, this accident would not present a significant hazard to the public.
>
> "6. Although no significant release of fission products to the sea is anticipated following a major reactor accident, the sea would provide important hold up and dilution for any fission products that might be released to the sea. Exposure of the shore population to fission products in the ocean following a maximum credible accident would be quite unlikely.
>
> "7. Underwater caisson containment is about $7,000,000 more expensive than conventional containment for a large boiling water reactor. However, the improved safety brought about by underwater containment may result in smaller exclusion and low-population zones, so that for sites with expensive land, underwater containment would reduce overall plant capital costs significantly.
>
> "8. Underwater containment should be considered for large power reactors near population centers where conventional land sites are not available, or where augmented reactor safety may be essential."
>
> (Klepper and Bell, 1968)

These general conclusions also apply to the offshore submerged plant with pressurized water reactor, except that out-leakage of fission products is even less likely against its greater submergence pressure. Questions that have not previously been considered in any depth are those of the potential effects on the marine biota and ecological balance of: the minute quantities of radioisotopes that would be released from present reactor plant designs into the sea; and the effects of fission product release on life in the plant's environs if there were a major nuclear accident.

It was recognized at the outset that there were substantial difficulties in answering these questions of thermal and radioactive effects on the marine ecological balance with any measure of precision:

1. Considerable variation in physiographic and biological conditions exists among potential offshore sites. A thermal discharge at one site might be beneficial to a fishery, where it would be harmful at another.
2. Waste discharges will vary considerably with the design of the plant. The radioisotopes that do escape from present plants and their quantities are not the same in all designs. With a virtually limitless supply of cooling water available, the designer of the offshore plant has great latitude in selecting a flow rate and temperature rise through the condensers to minimize detrimental thermal effects that might occur.
3. Ignorance prevails as to the exact ecological effects of heat, and more so, radiation over protracted periods, on most marine organisms. Radiation effects have been studied in great depth relative to man, but even here there is wide disagreement as to ultimate effects.

In view of these variations in environmental conditions and plant discharges, the undeveloped analytical technique, and the biological uncertainties, the following plan of attack was used:

1. The discharges from the plant and their potential effects were considered on a "worst case" basis.
2. It was decided to select several representative sites at widely separated geographic locales to typify distinct physiographic and biologic regimes. These sites were described, and were analyzed individually for their thermal fields at different seasons.

3. Present techniques for ascertaining the thermal field resulting from a single jet discharge were extended where necessary to describe the horizontal discharge of a hot water jet in deep water, with boundary conditions, stratification, and currents taken into account. The model was developed in nondimensional form, for ready adaptation to variations in plant discharge parameters and environmental conditions.

4. A specific pressurized water plant was studied in detail, with help from its manufacturer, for the radioisotopes that would escape from it in ordinary operation, and the fission products that might escape in a severe casualty. Although other designs would differ in some particulars from the one studied, this was considered to be a careful course in view of the "zero discharge" nuclear power plants now on the drawing boards.

The study was accordingly broken down into the following technical tasks:

1. Select representative power plant sites in northerly, temperate, and subtropical waters. Define the relevant physical and biological characteristics of the selected sites.
2. Analyze the thermal field resulting from the power plant's waste heat discharge. Apply the resulting model to specific sites, taking into account currents, density gradients, etc., insofar as the analytical procedures allow.
3. Define the radioactive wastes from the power plant and associated hazards for normal operating and casualty conditions.
4. Ascertain, where established, the biological tolerance levels of life in the plant's environs to power plant effluents, and predict the ecological effect of the effluents where possible.

SITE SELECTION

A survey was made of the Atlantic, Pacific, and Gulf coasts of the contiguous United States, for areas on the 250-ft isobath where the submerged power plant might be situated within 25 miles of land. Twelve site areas were selected initially, figure 3. The criteria for their selection were geographic distribution and, where a choice could be made within a region, proximity to land and to existing load centers or major power transmission networks. The 25-mile offshore distance limit was not based on the technical limitations of power transmission by submarine cables so much as a somewhat cautious assessment of the distance over which such transmission might be economically acceptable.

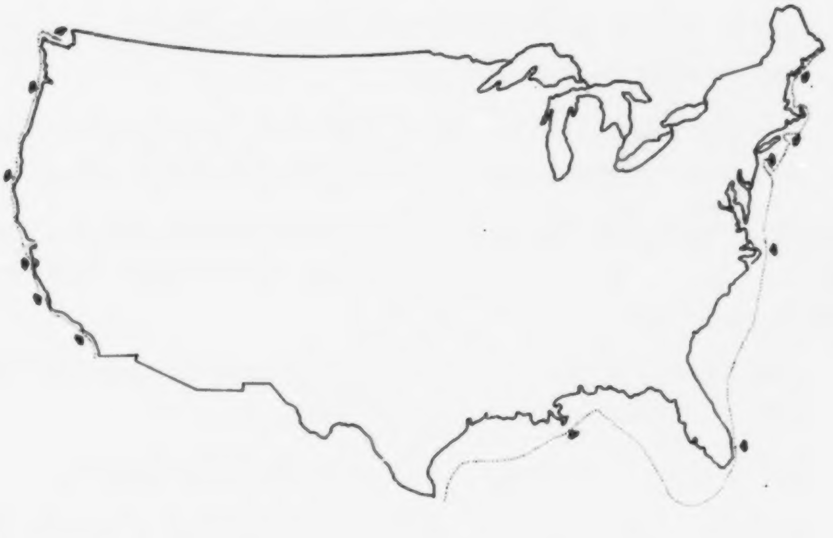

Figure 3. Distribution of Potential Sites

Two of the sites were eliminated in the preliminary evaluation because they were considered to be improbable on pragmatic grounds. That due south of the Mississippi delta because:

1. There seemed to be little motive to go offshore in this area in view of many potential riverside sites in an area of low popula-

tion density, on one of the largest rivers in the world. There is also less potential demand for nuclear power in this area because of the proximity of natural gas fields.

2. To serve a major load center, the offshore site would require a long "overland" tie through swampy bayou country.
3. The seabed off the delta is soft and would be subject to rapid siltation.
4. In any case, the off-delta site would be unique rather than one "representative" of the Gulf coastal area.

The site off Cape Hatteras was rejected because:

1. The tie from the beach to major transmission lines would be over lagoon and marsh terrain, and even more distant that at the delta site.
2. The area that would be served is one of modest population density and demand for electricity.
3. The plant emplacement site, near this "graveyard of the North Atlantic," might be more hazardous than other sites.

These eliminations reduced the areas to be considered to the ten below. For convenience, most of these were identified by a coastal landmark adjacent to the area studied.

1. Wiscasset, Maine: coastal area between latitudes 43° 30' and 43° 50' out to the 50-fathom isobath.
2. Block Island Sound and Eastern Long Island Sound.
3. Sea Girt, New Jersey: coastal area between latitudes 40° 00' and 15' out to longitude 73° 30'.
4. Miami, Florida: coastal area between latitudes 25° 40' and 27° 40' out to the 50-fathom isobath.
5. Puget Sound, Washington: east of 122° 30' longitude.
6. Tillamook Head, Oregon: coastal area between latitudes 45° 20' and 46° 10' out to the 50-fathom isobath.

7. Humboldt Bay, California: coastal area between latitudes 40° 20' and 50' out to the 50-fathom isobath.

8. Moss Landing, California: coastal area between latitudes 36° 30' and 37° 00' out to the 50-fathom isobath.

9. Morro Bay, California: coastal area between latitudes 35° 05' and 35' out to the 50-fathom isobath.

10. San Onofre, California: coastal area between latitudes 33° 10' and 30' out to the 50-fathom isobath.

The table below relates these sites to their distance from their probable shore ties.

		Approximate Distance to Tie (nm)	
Site Area	Shore Plant or Tie	Submarine Cable	Overland
Wiscasset	Maine Yankee	2-3	12-17
Block Island Sound	Millstone	4+	--
Sea Girt	Oyster Creek	20-30	20
Miami	Turkey Point or Fort Pierce	less than 5	--
Puget Sound	Various transmission lines	less than 1	--
Tillamook Head	Trojan Station	4	40+
Humboldt Bay	Humboldt Bay or Cottonwood*	10	--
Moss Landing	Moss Landing*	1	--
Morro Bay	Morro Bay*	1/2	8
San Onofre	San Onofre	1-1/2	5

*Nonnuclear central power stations

Oceanographic and biologic data were gathered on these areas in order to select from among them a smaller number of sites that would be fairly representative of their regions. Later in the study, the Gulf coast was reconsidered, because of the dearth of the sites there. Besides the previously rejected off-delta site, only one other area on the whole Gulf coast could be considered to fall within the depth and distance-from-shore groundrules of the study: this was a point due south of Pensacola, Florida, near the 25-nm limit. Data was gathered on the physical chracteristics of this site for use with the thermal field model, but limitations of time prevented a more thorough study of its biologic regime.

The data for the 10 areas above were then summarized, table 1, and the list reduced to four representative sites. The factors governing this reduction were:

1. To ensure inclusion of one semitropical area, one temperate area, and one northerly area.
2. To study areas of substantially different oceanographic conditions.
3. To study areas of different biologic regimes.
4. To exclude any site area that appeared to be an improbable location for the underwater power plant.

Areas having similar general conditions were first grouped. On the east coast, Wiscasset, either Block Island Sound or Sea Girt, and Miami, satisfied the conditions for a range of climatic conditions. The same groupings were also valid for thermal conditions and biologic province (Hedgpeth, 1957; Hazel, 1970). The Wiscasset and Miami areas were then obvious choices. Of Block Island Sound and Sea Girt, Block Island Sound in the area of the Race (at the eastern end of Long Island) was found to have current velocities that might be disadvantageous for emplacement of a power station. The Sea Girt area was believed to be more attractive for study purposes because it was in the interesting location of a submarine channel, it was farther from the coast (20 nm) than any site except that off Pensacola, and it would supply a major power consumption area (New York and Philadelphia). However, serious questions arose as to how representative the Sea Girt area really was in the biological sense. The site is near a sizable area of the New York Bight that has been contaminated by massive dumping of dredging spoil and sewage sludge, discharges from ships in the three major shipping lanes that converge on the Ambrose Light, and effluents from the badly polluted Hudson and East Rivers. The water in some places has almost no oxygen in it, and the seabed is devoid of visible life. It was felt then, that the area considered for the submerged power plant, although farther offshore, might be an anomaly in the large general field that is described as the Virginian biological province. Better bio-

Table 1. Summary of Site Conditions

Site	Climate	Biologic Province	Water Temperature $^{\circ}\mathrm{C}\ \frac{\text{Winter}}{\text{Summer}}$ Surface Range	Max Temp Difference to 225 ft	Current Conditions	Limitations as a Site
Wiscasset	"Northern"	Nova Scotian	$\frac{8.3-2.8}{18.8-10.0}$	$\frac{<1}{8.5}$	Combined coastal drift; tidal; upwelling	
Block Island Sound	Temperate	Virginian	$\frac{14.1-2.2}{22.3-11.6}$	$\frac{<1}{8}$	Very strong tidal	Currents very strong
Sea Girt	Temperate	Virginian	$\frac{11.2-3.6}{23.7-16.8}$	$\frac{1.5}{16.0}$	Shelf drift; rotary tidal	
Miami	Semi-tropical	Caribbean	$\frac{26.9-21.7}{29.7-28.2}$	$\frac{3.5}{16.0}$	Strong coastal drift; eddies	
Puget Sound	"Northern"	Aleutian	$\frac{12.9-4.9}{22.4-9.9}$	$\frac{1.4}{11.5}$	Weak currents	Poor bottom
Tillamook Head	"Northern"	Aleutian	$\frac{12.0-7.0}{17.9-9.0}$	$\frac{<1}{8}$	Variable	
Humboldt Bay	Temperate	Californian	$\frac{11.8-10.4}{15.7-8.4}$	$\frac{<1}{5}$	Seasonally changing drift	
Moss Landing	Temperate	Californian	$\frac{14.6-12.0}{14.9-9.8}$	$\frac{2}{5}$	Seasonally changing drift	
Morro Bay	Temperate	Californian	$\frac{15.8-11.4}{15.2-10.4}$	$\frac{3}{5}$	Seasonally changing drift	
San Onofre	Temperate	Californian	$\frac{19.0-12.9}{22.2-15.9}$	$\frac{4}{8}$	Seasonally changing drift	

logical information was available for the area from the eastern tip of Long Island through Block Island Sound, so it was decided to use this information as the basis for the biological description since, except in unusual circumstances, the prevalent biota vary very little with distance over the open continental shelf.

Of the west coast sites, two groupings were apparent from the climatic and biologic criteria: Puget Sound and Tillamook; and Humboldt Bay, Moss Landing, Morro Bay, and San Onofre. The two northerly sites were both the subject of concurrent EPA study projects, and it was decided that a better analysis of these sites would be possible after completion of those studies. It was also felt that Puget Sound was not really representative of "offshore" locations, and that the precipitous underwater escarpments of this fjord would make power plant emplacement there problematic. Of the four Californian sites, San Onofre differed from the others in thermal conditions. Since it was impractical within the time available to conduct a full analysis of more than four areas, it was decided to choose San Onofre as the final area for detailed study.

The four representative areas thus selected are, then: Wiscasset representing the Gulf of Maine; Sea Girt, representating a mid-Atlantic region; Miami representing semitropical waters off Florida; and the San Onofre area representing the waters off southern California.

These sites represent diverse environmental conditions. The site off southern Florida is a subtropical site on a narrow shelf (technically, the site lies on the continental slope), where conditions are dominated by a major oceanic current system, the Florida Current, practically to the exclusion of other factors such as winds and tide. Temperature and salinity are very uniform throughout the year. The waters are very warm and currents are strong. The circulation pattern is one of direct northward transport interspersed with small eddies, both mechanisms flushing shelf waters into the Florida Current at a relatively rapid rate. The site off Southern California is also on a narrow shelf (i.e., less than 12-nm wide) and the climate is warm-temperate with warm, dry summers and short, mild winters. The shelf waters derive principally from California Current waters that have been warmed up in the large eddy off Southern California. Shelf circulation patterns vary, being determined primarily by wind conditions. The site in the New York Bight, off Sea Girt, New Jersey, is the farthest offshore (about

20 nm) on the open shelf. The climate may be described as temperate. The site is the only one off the mouth of a major river, the Hudson, and the waters are made up of typical Atlantic shelf waters with admixture of river discharge in proportions that vary with the season. The water changes seasonably from well stratified to mixed, and circulation depends in uncertain proportions on many factors: winds, tide, coastal drift, river discharge, and topography. This Sea Girt site is unusual in that it is in the Hudson Channel, some 120 feet below the adjacent shelf. The Gulf of Maine site is in a more or less enclosed coastal sea having a boreal or "northerly" climate. Stratification is seasonal. The waters are from several sources, and the circulation is somewhat estuarine in character. Perhaps more than the other sites, the Gulf of Maine site is close to several estuaries.

Although other locations on the U.S. continental shelves would have different environmental conditions, the studied sites represent a good assortment of coastal areas where an offshore power plant might be placed, and with regard to coastal processes on the open shelf, most of the important factors are operative in one or more of these sites. Volume 2 of this report presents the descriptions of these four representative sites, on which the predictions of potential effects on the offshore marine environment of a submerged nuclear power plant are based.

REFERENCES

1. Marble, R. W., et al,"Offshore Submerged Nuclear Power-generating Station," Electric Boat division of General Dynamics, report P400-452-70, 130 pp, July 1970.
2. Bell, C.G., and Klepper, O.H., "Underwater Containment for Power Reactors," Nuclear Engineering Design 7, North-Holland Publishing Co., Amsterdam, pp 262-278.
3. Hedgpeth, J. (ed.) Treatise on Marine Ecology and Paleoecology, Chapter 13, pp 359-382, 1957.
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Section 4

NUCLEAR POWER PLANT WASTES

The wastes from an offshore nuclear power plant may be considered to fall into three categories:

1. The cooling water discharge from the plant's condensers.
2. Radionuclides that escape from the reactor plant during ordinary operation or that might escape in a nuclear casualty.
3. Other wastes occasioned by the presence of the plant or people, such as antifoulants or sewage.

The "thermal" discharge per se, being odorless, tasteless, and invisible, is a "waste" only to the extent that it promotes pollution or disrupts the ecological balance. Thermal transients or hydrodynamic buffeting experienced in passage through the condensers of a large plant can be sufficient to overstress or kill certain organisms, especially if the plant is not engineered to minimize such effects. Radionuclides are ordinarily released from nuclear power plants in quantities so minuscule that, until recently, many authorities would have considered them to be something less than a "waste," and as yet, there have been no nuclear casualties in commercial power plants that have eventuated in substantial release of radioactivity. Nevertheless, the growing number of nuclear power plants in operation, and the subtle ecological damages wrought by other pollutants once thought to be "harmless," have raised the issue of whether or not minute quantities of radionuclides in excess of the natural levels might be incrementally hazardous to life in some environs. The third category of wastes is little different from those that might emanate from an anchored ship. Until recently, at least, such wastes have been considered to be inconsequential in the open sea. That premise, too, may be subject to challenge in certain types of offshore environment. This section discusses these three categories of wastes, and gives the quantities and rates at which they might be released from a typical offshore nuclear power plant.

THERMAL DISCHARGE

To predict the environmental effects of an offshore nuclear power plant it is necessary to choose a power plant size and operating condition. Electric Boat division of General Dynamics has investigated in a company-financed study (R. W. Marble et al, 1970), the technical and economic feasibility of an

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offshore installation having an 1190-Mwe pressurized-water reactor plant. The preliminary design of this power plant was used in the present study to size components when this information had a bearing on the environmental results. For instance, the condenser flow rate affects the temperature to which organisms entrained in the cooling water are exposed and the duration of exposure.

The factor that has the greatest effect on the thermal discharge is the condenser heat rejection rate. The heat rejection rate chosen was 7.8 x 10^9 Btu/hr, which is the rate used in the design of the 1129-Mwe Forked River Station 1 in New Jersey, referred to elsewhere in this report (docket 50-363). This heat rejection rate corresponds with about 34 percent thermal efficiency for an 1190-Mwe power plant.

For a given condenser heat rejection rate, there is a wide range of cooling water flow rate and temperature rise that will meet the cooling requirements. For example, the cooling water temperature rise is about 60°F in the Forked River Station and about 20°F in the planned 819-Mwe Shoreham Nuclear Power Station on Long Island (docket 50-322). In the present study, a nominal value of 25°F is chosen for the temperature rise of the cooling water through the condenser. This temperature rise results in a corresponding cooling water flow of 1355 ft^3/sec or about 600,000 gpm for a heat rejection rate of 7.8 x 10^9 Btu/hr. These values are representative of those found in present-day nuclear power plants and are used throughout this study.

References

1. Abstract of a Long Island Lighting Co. report, "Environmental Statement, Shoreham Nuclear Power Station, Plant Unit 1," docket 50-322, 1 June 1970.

2. "Preliminary Safety Analysis Report, Forked River Nuclear Station, Unit 1," Jersey Central Power and Light Co., docket 50-363, revised 15 July 1970.

3. R. W. Marble et al, "Offshore Submerged Nuclear Power Generating Station," report P400-452-70, Electric Boat division of General Dynamics, July 1970.

RADIONUCLIDE RELEASE TO THE SEA

Radionuclides that would be released to the sea by a typical pressurized water reactor in an undersea power plant were analyzed. More than half of the commercial power plants in operation or projected for construction at the present time employ this type of reactor. Radionuclides originate in three ways.

1. Fission products generated within a fuel rod may leak into the primary coolant water through a defect in the fuel rod cladding. "Tramp" uranium, which occurs as dust on the outside of the fuel rod, fissions and introduces fission products directly into the primary coolant. A one-percent defect in fuel rod cladding is assumed for safety analysis though normal operation is expected to have less.
2. Activation of corrosion products in the reactor coolant system produces radionuclides in the primary coolant. Most activity comes from material eroded outside the core, deposited in the core, and re-released to the primary coolant. A zirconium alloy is selected for the fuel cladding because of its low corrosion rate and low production of radionuclides. The primary coolant piping, steam generator, and pumps are usually stainless steel.
3. Impurities or additives in the primary coolant become activated when deposited in the core or when passing through it.

Normal Plant Operation

A short description of the power plant operation is necessary to understand the paths by which radionuclides enter the environment. The primary coolant gains heat in passing through the core, loses heat through the steam generator, and is pumped back to the core. The secondary coolant vaporizes in the steam generator, leaves the reactor compartment, propels the turbine blades, liquefies in the condenser, and is pumped back to the steam generator in the reactor compartment. Sea water passes through the condenser and back to the sea at a higher temperature. During normal plant operation, liquids are collected that contain radionuclides, most of which are removed by a waste management system similar to that represented by figure 4. If the trace amounts of radionuclides remaining in the liquid waste are below those of government specifications, the waste is discharged into the sea via the condenser cooling water.

The power plant is contained by a 110-foot diameter cylindrical pressure hull with a hemi-head on each end. The pressure hull rests on the sea-floor at a depth of 200 to 250 feet, with the reactor compartment located at one end of it. The pressure hull and one bulkhead constitute the containment vessel in the event of a nuclear accident. Fresh air is supplied to personnel spaces by forced circulation of atmospheric air via a trunk from the surface to the pressure hull. Any release of gaseous fission products within the plant space will be circulated to the surface via the fresh air ventilation system and released to the atmosphere. This method of gas release is the same as that of present land-based nuclear power plants having pressurized water reactors.

Reactor Operation

The most economical reactor is the one with maximum core life (time between refuelings). To achieve this, a commercial reactor is controlled by boron compounds dissolved in the primary coolant instead of by mechanically driven control rods. Because the boron is homogeneously distributed throughout the coolant, the power density is more uniform than in a rod-controlled core. The average core temperature in the boron-controlled core is closer to the peak temperature in the hottest channel than in the rod-controlled core. Since the core is temperature limited by the hottest channel, the average core temperature and average coolant outlet temperature are higher in a boron-controlled core. The power output for the same size of core and uranium loading is greater for the boron-controlled core than for the rod-controlled core. Consequently, there is more efficient fuel utilization with boron control.

During the life of the core,the boron concentration is progressively reduced to compensate for the burnup of uranium 235 and so maintain a critical core. During normal operation, a power reduction is followed by an increase in xenon 135 concentration to a maximum, which is followed by a decrease to an equilibrium concentration. Xenon 135 is a fission product and a strong absorber of neutrons. The maximum xenon concentration, which occurs about ten hours after the power change, must be offset by a temporary reduction in the boron concentration in the primary coolant to maintain criticality. The boron concentration is reduced by removing primary coolant and replenishing with pure water, and is subsequently increased by removing primary coolant and replenishing with water having a high boron content. The primary coolant removed in maintaining the proper boron concentration is called primary coolant letdown. The letdown is processed in the waste management system for reclamation of boron and removal of radionuclides.

Waste Management System

The purpose of the waste management system, represented by figure 4, is to reduce the radionuclide release for normal power plant operation to acceptable levels. Maximum permissible concentrations of each radionuclide release are specified in reference 1 (10 CFR 20). Present practice is to design the system so that the radionuclide release is below specified limits by a factor of 100 or more. Some reactor manufacturers are promoting a "zero" release system in which radionuclide release is minimized by drumming all liquid and solid wastes and bottling all the gaseous wastes. Such a system has advantages for the power plant environment, but it raises problems in the storage, transportation, and disposal of the containers.

A typical waste management system for a pressurized water reactor in an undersea power plant is derived from current nuclear power plants on land. Quantities of primary coolant water containing boron, fission products, and erosion and corrosion products, are collected mostly as the result of changing the boron concentration in the primary coolant during changes in power level. Leaks and sampling of primary coolant are other sources of liquid waste.

The recoverable primary coolant waste is processed in the boron recovery system. This liquid waste is sprayed into a flash tank to remove hydrogen and fission gases. The liquid waste then goes to holdup tanks, to a filter and an ion exchanger, and then to the boric acid concentrator. The bottoms from the concentrator may go the boric acid makeup tanks for reuse or be drummed off for disposal. The distillate from the concentrator passes through an ion exchanger and is then stored in tanks for reuse, further processing, or release to the sea.

The remaining liquid wastes are collected in the miscellaneous waste tank, where defoaming or neutralizing agents may be added as required for efficient concentrator operation. The wastes are filtered and enter the concentra-

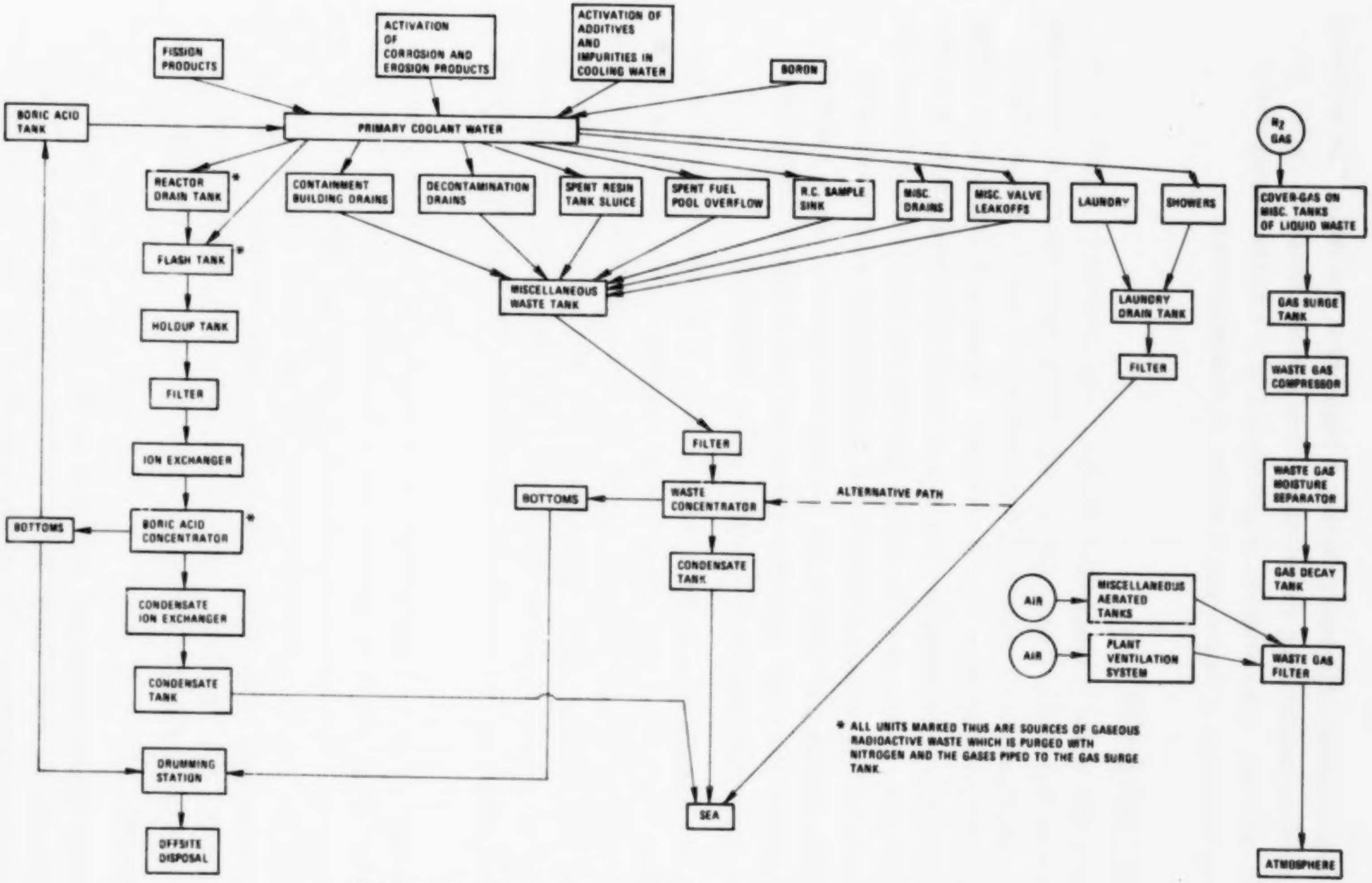

Figure 4. Radioactive Waste Management System

tor where the concentrates are collected and drummed off for disposal. The condensate is transferred to a tank for eventual release to the sea, though its limited reuse might be possible.

All liquid waste is analyzed for radioactive content prior to discharge to the sea. Inadvertent discharge is prevented by having two valves, one of which closes automatically if the radiation level of the liquid discharge exceeds a preset limit.

Gaseous wastes originating in the cover-gas system for the liquid waste tanks are swept out by nitrogen to a surge tank and compressed into the gas decay tank. The waste gases may remain in the decay tank for a period of thirty to forty days until most radioactivity other than Kr85 decays away. The gases are then released to atmosphere via the ventilation system, in concentrations well below those of 10CFR20 (reference 1). The potential hazards of releasing radioactive gases to the atmosphere are analyzed in the safety reports of current land-based plants. The analysis for the underwater plant is the same and not repeated for this study.

Any small gas leaks from the primary coolant loop, or from the waste management system, are detected by an air radiation monitoring system. Any gases released in the plant spaces are sent to the atmosphere via the ventilation system.

Radionuclide Release

The quantities of radionuclides released from a nuclear power plant are calculated and given in the preliminary safety analysis report (PSAR) required for licensing. This calculation is based on an assumed one percent defective fuel element cladding. The quantities may vary somewhat among power plants due largely to the degree of conservatism used in the calculations. Differences in the site and design of the reactor coolant purification and waste management systems also lead to some variation in the calculated releases.

Two pressurized water plants that represent the latest in nuclear power plant design were examined for their amounts of radionuclide release. They are:

1. Forked River Nuclear Station, Unit 1, owned by the Jersey Central Power and Light Company; reactor built by Combustion Engineering; power level is 3390 Mwt or 1129 Mwe (reference 2)

2. Trojan Nuclear Plant, owned by the Portland General Electric Company; reactor built by Westinghouse; power level is 3423 Mwt or 1106 Mwe (reference 3).

The predicted quantities of radionuclides released by the Forked River plant (table 2), are generally higher than those of the Trojan plant (table 3), and are therefore chosen for this environmental study. The radionuclides in table 2 include those given in the preliminary safety analysis report (PSAR, reference 2), plus all fission products having a half-life of more than six hours and a yield higher than 10^{-3} percent. Radionuclides with yields of less than 10^{-3} percent are not produced in quantities that have significant concentration in the sea.

Since there are no apparent hard and fast rules by which to qualify nuclides for PSAR analysis, reasons for choosing those listed in the tables are given below. For convenience, the nuclides are grouped into gases, halogens, and volatile solids that diffuse through the UO_2 and enter the reactor coolant through assumed cladding defects; a fourth group consists of important activation products expected to originate in the primary coolant.

Gases -- The gaseous isotopes Kr and Xe are the primary sources of radiation to be handled in the N_2-purging system shown by figure 4, and are among the main contributors to the whole body dose received offsite from airborne activity released during postulated incidents.

Halogens -- The halogens are considered to be sources of radiation in the liquid waste system, and are also main contributors of the offsite dose because of their assimilation and retention by the human body. They are retained particularly by the thyroid.

Volatile Solids and Daughters in the Decay Chains -- In general, radioactive nuclides in this group, such as cesium, strontium, and ruthenium are considered because of their affinity for the human body, and their retention in the food chain. Others, such as molybdenum and yttrium, are considered because of their apparent lack of retention by the purification system, thus allowing some buildup in the reactor coolant.

Activation Products -- Nuclides in this group, such as cesium-134, tritium, and corrosion products, are considered because of their relative abundance due to the chemistry and materials of the Combustion Engineer-

Table 2. Forked River Nuclear Station -- Unit 1 Predicted Radioactive Liquid Discharge Operating with One Percent Fuel Cladding Defects

Nuclide	Annual Discharge (Curies)	Maximum Average Concentration ($\mu Ci/cm^3$)
H-3*	385.0	5.23(-6)
Cr-51*	5.85(-3)#	1.68(-10)
Mn-54*	4.19(-5)	1.21(-12)
Fe-55	2.30(-4)	5.80(-12)
Co-58*	7.20(-3)	2.05(-10)
Fe-59*	3.24(-5)	9.39(-13)
Co-60*	9.00(-4)	2.30(-11)
Ge-78	3.31(-8)	9.50(-16)
As-78	6.50(-8)	1.85(-15)
Br-84*	1.00(-3)	2.90(-11)
Rb-88*	5.50(-2)	1.59(-9)
Rb-89*	1.36(-3)	3.95(-11)
Sr-89*	1.43(-4)	4.04(-12)
Sr-90*	3.19(-6)	1.91(-13)
Y-90*	1.06(-4)	5.54(-12)
Sr-91*	8.36(-5)	2.40(-12)
Y-91*	7.59(-2)	1.42(-9)
Y-93	5.98(-4)	1.84(-11)
Zr-95*	1.44(-6)	4.12(-14)
Nb-95	1.48(-4)	4.53(-12)
Zr-97	6.60(-5)	1.90(-12)
Mo-99*	4.10(-1)	1.17(-8)
Ru-103*	1.16(-4)	3.31(-12)
Rh-105	1.16-(5)	4.65(-13)
Ru-106*	4.46(-6)	1.91(-13)

*Nuclide from PSAR list (ref 2); other nuclides are added for this study.

#( ) denotes power of 10

Table 2 (Continued)

Nuclide	Annual Discharge (Curies)	Maximum Average Concentration (μCi/cm^3)
Pd-109	3.16(-7)	9.10(-15)
Ag-111	4.28(-7)	1.24(-14)
Cd-115	6.05(-8)	1.77(-15)
Sn-119m	2.04(-7)	7.90(-15)
Sn-121	1.38(-7)	3.88(-15)
Sn-123	1.17(-8)	3.35(-16)
Sn-125	1.30(-9)	2.54(-17)
Sb-125	1.03(-7)	5.48(-15)
Te-125m	1.06(-5)	3.66(-13)
Sb-126	2.33(-8)	6.76(-16)
Sb-127	2.84(-6)	8.25(-14)
Te-127m	3.90(-5)	1.49(-12)
Te-127	1.65(-4)	4.95(-12)
Te-129m	2.05(-6)	2.45(-11)
Te-129*	6.66(-4)	1.91(-11)
I-129*	1.27(-9)	5.43(-17)
Te-131m	6.55(-4)	1.89(-11)
I-131*	1.08(-1)	3.13(-9)
Te-132*	8.64(-3)	2.49(-10)
I-132*	2.54(-1)	7.35(-10)
I-133*	1.40(-1)	4.03(-9)
Te-134*	5.67(-4)	1.63(-11)
I-134*	1.34(-2)	3.87(-10)
Cs-134*	4.64(-1)	2.74(-8)
I-135*	6.19(-2)	1.79(-9)
Cs-136*	3.00(-2)	7.97(-10)
Cs-137*	4.43	1.00(-7)
Cs-138*	1.23(-1)	3.56(-9)
Ba-140*	1.71(-4)	4.84(-12)
La-140*	1.65(-4)	4.70(-12)
Ce-141	1.50(-4)	4.35(-12)

Table 2 (Continued)

Nuclide	Annual Discharge (Curies)	Maximum Average Concentration (μCi/cm^3)
Ce-143	1.43(-4)	4.16(-12)
Pr-143*	1.49(-4)	4.27(-12)
Ce-144*	7.70(-5)	2.95(-12)
Pr-145	2.20(-5)	6.35(-13)
Nd-147	5.10(-5)	1.48(-12)
Pm-147	1.10(-5)	5.85(-13)
Pm-149	1.93(-5)	5.62(-13)
Pm-151	6.05(-6)	1.75(-13)
Sm-151	7.05(-8)	4.30(-15)
Sm-153	3.64(-6)	1.05(-13)
Eu-155	1.14(-7)	6.23(-15)
Eu-156	3.22(-7)	9.30(-15)
Eu-157	7.00(-8)	2.01(-15)
Gd-159	1.24(-8)	3.56(-16)

Table 3. Trojan Nuclear Plant
Estimated Annual Liquid Release by Isotope

Isotope	Estimated Annual Release (μCi)
Mn-54	0.21
Mn-56	0.01
Co-58	6.67
Fe-59	0.28
Co-60	0.20
Sr-89	1.53
Sr-90	0.46
Y-90	0.03
Sr-91	0.12
Y-91	0.16
Mo-99	5.66(2)#
I-131	7.96(2)
Te-132	7.62(1)
I-132	0.24
I-133	6.28(2)
Cs-134	5.91(1)
I-135	6.13(1)
Cs-136	8.27
Cs-137	3.19(2)
Ba-140	0.08
La-140	0.21
Ce-144	1.11
H-3	4.77(9)
Unidentified	1.99(3)

#( ) denotes power of 10

ing (CE) reactor coolant system. Cs-134 is produced by the activation of Cs-133, a daughter of the principal fission gas Xe-133. Most of the tritium is due to activation of the boron, deuterium, lithium, and nitrogen in the coolant. Corrosion products are, of course, released from the system materials.

Many radioactive nuclides in the groups above were rejected because of low yield, short half-life, rejection by or lack of affinity for the human body, lack of retention in the food chain, or chemical similarity with a more radioactive isotope.

Two quantities are given in table 2: the annual discharge in curies, and the "maximum average" concentration in μCi/cc. Each quantity is calculated independently. The major difference between the two calculations is the choice of assumptions. A conservative assumption for one calculation may be ultraconservative and not used for the other. Consequently, the two quantities are not easily related.

The calculation of annual discharge is based on the amount of fission and activation products produced and available for release during the last year of operation of one core. Of all the fission products produced during the year, 1 percent is assumed to occur in the failed fuel elements. Fission product leakage into the primary coolant from these 1 percent failed fuel elements is calculated from escape rate coefficients (see table 11-2, reference 2) which are conservatively based on measured fission product leakage rates from perforated fuel elements heated to centerline melting temperature in an autoclave. These fission products are carried by normal amounts of primary coolant letdown and leakage, and are processed by the waste management system. The resultant curies of liquid waste are presented as annual discharge in table 2.

The "maximum average" concentration is calculated as follows. At some time during three equilibrium core cycles each radionuclide reaches a maximum concentration in the primary coolant. Although these maxima occur at different times for different radionuclides, they are conservatively assumed to occur at the same time for this calculation. Thus: assume normal letdown and leakage of the maximum activity primary coolant for one year, and assume that this radioactive waste is processed by the waste management system. Divide the maximum release of each radionuclide by the volume of water that passes annually through the condensers of the Forked River power plant, operating at 80 percent of maximum power. The resulting quotient is the "maximum average" concentration found in table 2. This concentration is maximum because the maximum activity of the primary coolant is assumed to exist for one year, and is average because continuous release is assumed. Note that the intake water for condenser cooling is assumed to have zero radionuclide concentration. Actually, the intake concentration is not expected to exceed 1 percent of the discharge concentration, based on concentrations calculated in the radionuclide distribution section of this report. The maximum annual release of each radionuclide based on maximum activity of the primary coolant is about 10 times larger than the annual discharge in table 2, because of differences in conservative assumptions. Much of the conservatism is caused by the unlikely assumption that maximum activity exists in the primary coolant for one year.

An additional 2.6 factor of conservatism in the maximum average concentration for the underwater power plant is accounted for by the difference in cooling water flow rate between it and the Forked River plant. The condenser cooling water flow rate is 608,000 gpm for the underwater power plant, as against 230,000 gpm for the Forked River plant. Consequently, the maximum average concentrations of table 2 correspond with 40 percent of maximum condenser cooling flow for the underwater power plant.

Other cautious assumptions are made: the discharge and concentrations in table 2 are based on operation with 1 percent failed fuel cladding; and no reduction in the amount of radionuclides from natural decay during waste processing is taken into account.

In spite of these compounded conservatisms in the maximum average calculations, it is possible to exceed these concentrations for limited periods, since discharge of the liquid waste is normally done in batches instead of continuously. The batch releases are made at the discretion of the plant operator.

The liquid waste is sampled and analyzed for radioactive content prior to disposal. If discharge directly to the environment is permissible, a flow indicator and appropriate valving will permit controlled release from the condensate tank. The condenser coolant flow rate varies with power level, and must be considered by the operator before dumping. It is common practice for the operator not to dump, if radionuclide concentrations in the condenser coolant discharge will exceed one-tenth of the maximum permissible concentrations in drinking water. This guideline is not known to be documented. The flow rate and activity of all liquids discharged from the waste disposal system will be indicated, recorded, and alarmed. However, the alarm is set at about 20 percent above the measured activity level in the condensate tank as a safety feature, so that discharging a mass of highly radioactive liquid will activate the interlock and stop the discharge. Comparison of annually averaged concentrations with the maximum permissible concentrations of radionuclides is made in section 8.

The normal releases of gaseous radionuclides from the Forked River and Trojan plants are given in tables 4 and 5, respectively. Since the normal release is composed of noble gases, is vented to the atmosphere, and does not enter the marine environment in significant amounts, this type of release is not further studied in this report.

Qualifying Accidents

To qualify for analysis in this report, accidents must meet two essential stipulations:

1. They must be credible; that is, conform with the criteria of credibility set forth in the AEC report on reactor safety and containment (reference 4).
2. Radionuclides must be released to the sea.

Only the following two credible accidents can result in radionuclide release to the sea, and therefore qualify for analysis.

Loss of Primary Coolant

First is the most serious accident that could occur in current nuclear plants: this is a double break in the primary coolant pipe, with the coolant flashing to steam within the containment vessel. The radioactive impurities and corrosion products of the primary coolant are carried with the steam. The fission products released from the core to the containment vessel are:

Table 4. Forked River Nuclear Station -- Unit 1 Annual Radioactive Gas Discharges Based on Operation with One Percent Failed Fuel

Nuclide	Average Annual Discharge (Curies)	Average Annual Concentration (μCi/cc)	Maximum Permissible Concentration (μCi/cc)	Fraction of Maximum Permissible Concentration
Kr-85	2436.0	1.10(-9)#	3(-7)	3.67(-3)
Xe-131m	70.6	5.37(-11)	4(-7)	1.35(-4)
Xe-133	238.0	1.91(-10)	3(-7)	6.39(-4)

Table 5. Trojan Nuclear Plant Estimated Annual Gaseous Release by Isotope

Isotope	Estimated Annual Release (Curies)
Kr-85	24,800
Kr-85m, 87, 88	negligible
Xe-133	5,200
Xe-135, 138	negligible

#( ) denotes power of 10

100 percent of the noble gases
50 percent of the halogens
1 percent of the solids

These percentages are assumed in the safety analysis of all pressurized water plants for site evaluation, and originate in the report by DiNunno et al (reference 5). They result in quantities that are extremely conservative since the engineered safeguards system prevents melting of the fuel or cladding. A leakage rate of 0.1 percent per day is assumed for the contents of the containment vessel to the surrounding environment. This is conservatively estimated to be about 10 times higher than the expected rate. For the undersea power plant, the containment vessel is the pressure hull and the reactor compartment bulkhead. The reactor compartment is at one end of the pressure hull, and any leakage out of the containment vessel would most probably occur through the bulkhead for the following reasons:

1. The pressure difference between the reactor compartment and the plant spaces is greater than the pressure difference between the reactor compartment and the sea. In a loss-of-coolant accident, the peak pressure within the containment vessel would be 80 to 85 psig. The pressure in the rest of the plant is atmospheric. If the plant is resting on the bottom of the sea at about 200 feet and the pressure hull is 110 feet in diameter, the top of the plant is 90 feet below the surface where the sea water pressure is 39 psig. Consequently, the pressure drop across the bulkhead to the plant spaces is 80 to 85 psig, and across the pressure hull to the sea is 41 to 46 psig at the top, decreasing and changing sign toward the bottom.
2. The bulkhead has many more penetrations than the pressure hull, thus offering a higher probability of leakage.

In an actual accident, most of the radionuclides leak into the turbine room and are subsequently sent to atmosphere by the ventilation system. Since the radionuclide leakage to the sea is not known, the full 0.1 percent per day leakage is, for the purpose of this study, assumed to go to sea. A porous weld in the hull could be responsible for such leakage, which is taken as (reference 5):

100 percent of the noble gases
25 percent of the halogens
1 percent of the solids

The other 25 percent of the halogens is assumed to plate out within the containment vessel. The rate of release of each radionuclide is calculated from the foregoing assumptions. At about 20 seconds after the accident, the pressure rises to the maximum of 80 to 85 psig, and at this time the safeguard spray turns on to cool the reactor compartment, and decrease the pressure. In about 15 minutes, the pressure drops below the sea pressure of 39 psig and leakage to the sea ceases. The variation in containment vessel pressure with time after the accident is shown in figure 5. This figure was derived for a land-based power plant and multiplied by the free volume ratio of the surface plant to the underwater plant.

The inventory of radionuclides in the core at shutdown is given in table 6. The amount of each radionuclide released to the sea following a loss-of-coolant accident, equals the amount in the core inventory, times the fraction released to the containment vessel, times the constant leakage rate of 0.1 percent/day for 15 minutes. Those amounts are given in table 6. The accident is analyzed as a batch release.

Breach of Containment

The second qualifying accident is a breach of the pressure hull by collision with a submarine or a sinking ship. The breach occurs in the reactor compartment. It is assumed that the containment vessel has no shield for external missiles. Sea water floods the reactor compartment and a primary coolant pipe opens through thermal or mechanical shock. The coolant escapes instantaneously to the sea water, discharging the radionuclides originating from one percent failed fuel elements. The inventory of radionuclides in the reactor coolant is given in table 7 for the Forked River plant. Emergency core cooling, and cooling by sea water, prevent melting of the fuel or cladding. A convection cooling loop from the core to the sea removes after-heat in the event of a total power failure within the plant. However, we assume that the sudden pressure drop in the primary coolant loop causes perforations in 99 percent (say, 100 percent for practical purposes) of the cladding, which is of

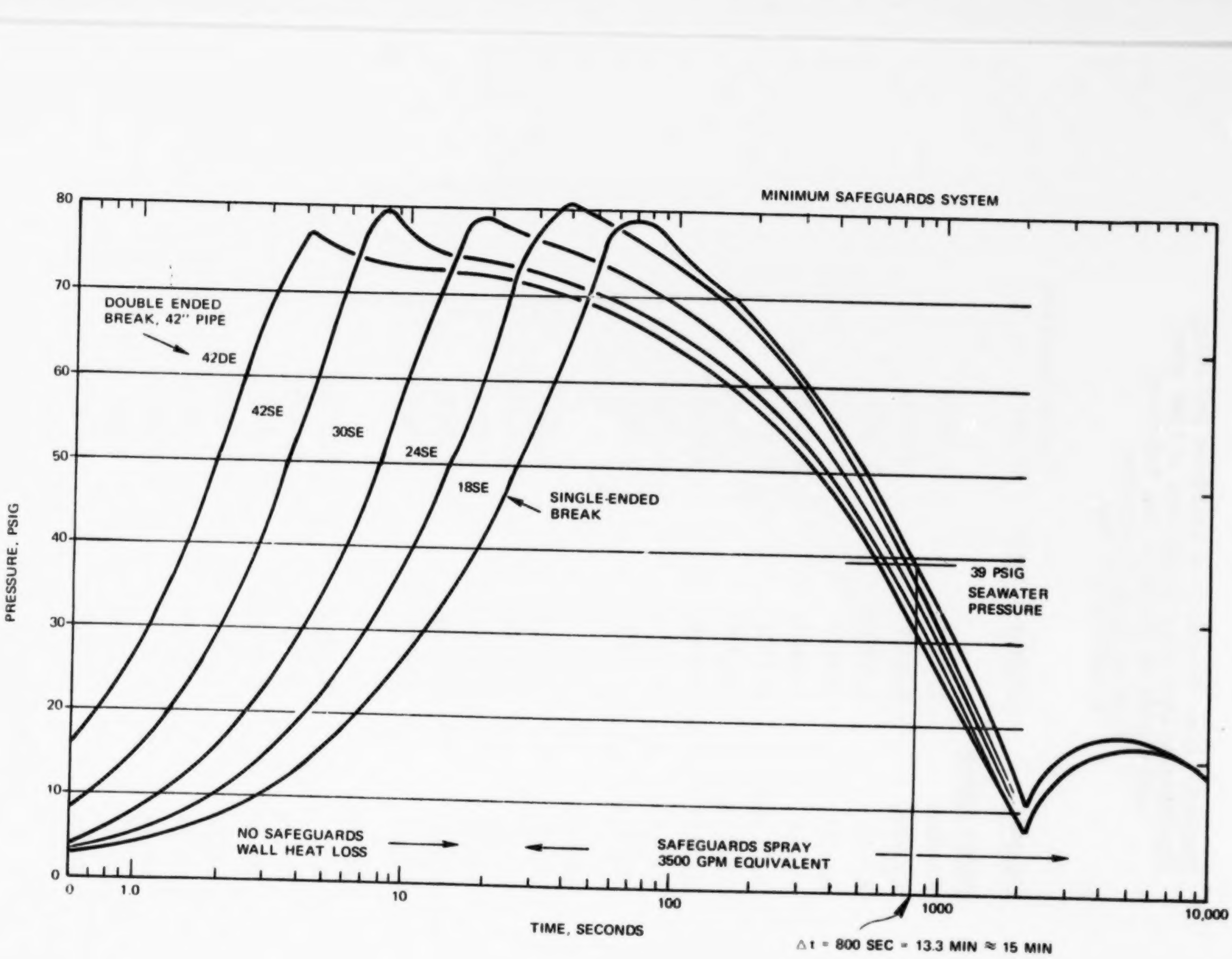

Figure 5. Pressure in Containment Vessel Versus Time After Loss-of-Coolant Accident

Table 6. Core Inventory at Shutdown Following Equilibrium Operating Conditions at 3560 Mwt, and Curies Released to Sea Following Loss of Coolant Accident Forked River Plant

Nuclide	Curies in Core	Curies Released to Sea
Noble Gases		
Kr-83m	1.57(7)#	1.63(2)
Kr-85m	3.93(7)	4.09(2)
Kr-85	1.08(6)	1.12(1)
Kr-87	7.56(7)	7.86(2)
Kr-88	1.08(8)	1.12(3)
Xe-131m	6.65(4)	6.91(-1)
Xe-133m	5.14(6)	5.35(1)
Xe-133	2.02(8)	2.10(3)
Xe-135	4.37(7)	4.55(2)
Xe-138	1.78(8)	1.85(3)
Iodines		
I-131	8.78(7)	2.28(2)
I-132	1.31(8)	3.41(2)
I-133	2.02(8)	5.25(2)
I-134	2.36(8)	6.14(2)
I-135	1.86(8)	4.84(2)
Solids		
H-3	2.82(4)	2.93(-3)
Br-84	2.79(7)	2.90(0)
Rb-88	1.08(8)	1.12(1)
Rb-89	1.43(8)	1.49(1)
Sr-89	1.43(8)	1.49(1)
Sr-90	8.23(6)	8.56(-1)
Y-90	8.23(6)	8.56(-1)
Sr-91	1.74(8)	1.18(1)

# ( ) denotes power of 10

Table 6 (Continued)

Nuclide	Curies in Core	Curies Released to Sea
Y-91	1.77(8)	1.84(1)
Mo-99	1.85(8)	1.93(1)
Ru-103	9.01(7)	9.38(0)
Te-127m	1.05(6)	1.09(-1)
Te-129m	1.05(7)	1.09(0)
Te-129	2.70(7)	2.81(0)
Te-132	1.28(8)	1.33(1)
Te-134	2.07(8)	2.15(1)
Cs-134	1.92(6)	2.00(-1)
Cs-136	1.08(5)	1.12(-2)
Cs-137	8.38(6)	8.71(-1)
Cs-138	2.02(8)	2.10(1)
Ba-140	1.89(8)	1.97(1)
La-140	1.90(8)	1.98(1)
Pr-143	1.77(8)	1.84(1)
Ce-144	1.35(8)	1.40(1)

course a cautious assumption. The activity in the fuel rod gap (the space in the rod between the fuel pellet and the cladding) is released to the sea, table 8. There are sufficient control rods in the core to prevent supercriticality when it is flooded with sea water. The accident is analyzed as a batch release to the sea of all the radionuclides in tables 7 and 8.

A breach of containment may also occur during refueling, but negligible radioactivity is released to the sea. For refueling, the pressure vessel head is removed, exposing the core with control rods in and flooded with borated water slightly above room temperature. No gap release occurs since there is no sudden pressure drop that might cause a cladding perforation. Coolant activity is substantially reduced prior to refueling by purification and dilution, and the core is designed so that flooding with sea water will not cause supercriticality.

Nonqualifying Accidents

Accidents found to release radionuclides to plant space or the atmosphere, but not the sea, are listed here. The amount released is below 10CFR20 limits.

1. Liquid waste from a leakage or ruptured holding tank enters a drain and is pumped back into the waste management system.
2. Gaseous waste leaks from the pressurized gas decay tank. The gas escapes to the plant space and is ventilated to atmosphere. It may be possible to contain the waste in one compartment of the plant and then control its release to the atmosphere.
3. In the case of dropping and breaking a bundle of spent fuel elements in the fuel pool, the gaseous radionuclides are released to the space above the pool and thus ventilated to atmosphere. The possibility exists of containing the gas in one compartment and then controlling its release to the atmosphere.
4. A primary to secondary leakage occurs from a break in a steam generator tube. If the leak is one gpm or less, plant operation continues and radionuclides are released via the air ejector and blowdown. The liquid wastes are routed to the waste management

Table 7. Maximum Fission and Corrosion Product Activity in the Reactor Coolant at 70°F Forked River Nuclear Station - Unit 1

Nuclide		Specific Activity (μCi/cm^3)	Coolant Inventory (Curies)
H-3	fission	.1849	
	activation in coolant	.5495	
	CEAs	.0128	
	total	.7472	1.18(2)
Cr-51		5.32(-3)#	1.29
Mn-54		3.85(-5)	9.3(-3)
Fe-55		1.86(-4)	4.5(-2)
Co-58		6.52(-3)	1.58
Fe-59		2.98(-5)	7.2(-3)
Co-60		7.27(-4)	1.76(-1)
Ge-78		2.47(-6)	5.97(-4)
As-78		4.83(-6)	1.17(-3)
Br-84		7.52(-2)	1.82(1)
Kr-85m		2.41	5.83(2)
Kr-85		5.42	1.31(3)
Kr-87		1.30	3.14(2)
Kr-88		4.19	1.01(3)
Rb-88		4.13	1.00(3)
Rb-89		1.02(-1)	2.48(1)
Sr-89		1.05(-2)	2.54
Sr-90		4.95(-4)	1.20(-1)
Y-90		1.72(-3)	4.16(-1)
Sr-91		6.24(-3)	1.51
Y-91		4.40(-1)	1.06(2)
Y-93		5.71(-3)	1.38
Zr-95		1.31(-6)	3.17(-4)
Nb-95		1.17(-2)	2.83
Zr-97		4.93(-3)	1.19

#(   ) denotes power of 10

Table 7 (Continued)

Nuclide	Specific Activity (μCi/cm^3)	Coolant Inventory (Curies)
Mo-99	3.63	8.79(-2)
Ru-103	8.60(-3)	2.08
Rh-105	1.21(-3)	2.93(-1)
Ru-106	4.96(-4)	1.20(-1)
Pd-109	2.36(-5)	5.71(-3)
Ag-111	3.23(-5)	7.81(-3)
Cd-115	4.59(-6)	1.11(-3)
Sn-119m	2.06(-5)	4.98(-3)
Sn-121	1.04(-5)	2.52(-3)
Sn-123	8.7(-7)	2.10(-4)
Sn-125	9.68(-8)	2.34(-5)
Sb-125	1.42(-5)	3.43(-3)
Te-125m	9.5(-4)	2.30(-1)
Sb-126	1.76(-6)	4.26(-4)
Sb-127	2.14(-4)	5.18(-2)
Te-127m	3.9(-3)	9.35(-1)
Te-127	1.29(-2)	3.12
Te-129m	6.4(-2)	1.55(1)
Te-129	4.97(-2)	1.20(1)
I-129	1.44(-7)	3.49(-5)
Te-131m	4.91(-2)	1.19(1)
I-131	8.12	1.97(3)
Xe-131m	3.55	8.59(2)
Te-132	6.47(-1)	1.57(2)
I-132	1.91	4.62(2)
I-133	1.05(1)	2.53(3)
Xe-133	3.52(2)	8.53(4)
Te-134	4.24(-2)	1.03(1)
I-134	1.01	2.44(2)
Cs-134	7.11	1.72(3)
I-135	4.65	1.13(3)

Table 7 (Continued)

Nuclide	Specific Activity (μCi/cm^3)	Coolant Inventory (Curies)
Xe-135	1.17(1)	2.84(3)
Cs-136	2.46(-1)	5.95(1)
Cs-137	3.11(1)	7.52(3)
Xe-138	5.74(-1)	1.39(2)
Cs-138	1.10	2.67(2)
Ba-140	1.26(-2)	3.04
La-140	1.22(-2)	2.96
Ce-141	1.13(-2)	2.73
Ce-143	1.08(-2)	2.61
Pr-143	1.11(-2)	2.69
Ce-144	7.67(-3)	1.86
Pr-145	1.64(-3)	3.97(-1)
Nd-147	3.85(-3)	9.31(-1)
Pm-147	1.52(-3)	3.68(-1)
Pm-149	1.46(-3)	3.53(-1)
Pm-151	4.55(-4)	1.10(-1)
Sm-151	1.12(-5)	2.71(-3)
Sm-153	2.73(-4)	6.60(-2)
Eu-155	1.62(-5)	3.29(-3)
Eu-156	2.42(-5)	5.85(-3)
Eu-157	5.21(-6)	1.26(-3)
Gd-159	9.27(-7)	2.24(-4)

Table 8. Maximum Fission Product Activity in the Fuel Gas Gap
Forked River Nuclear Station - Unit 1

Nuclide	Activity (Curies)
Kr-85	4.69(5)#
Kr-85m	8.58(5)
Kr-87	9.11(5)
Kr-88	1.93(6)
Xe-131m	6.78(4)
Xe-133	1.99(7)
Xe-133m	3.22(6)
Xe-135	5.86(6)
Xe-135m	2.97(5)
Xe-138	9.03(5)
I-131	1.52(7)
I-132	3.97(6)
I-133	1.53(7)
I-134	4.45(6)
I-135	9.31(6)

#( ) denotes power of 10

system and the gaseous waste is discharged to atmosphere. If the radionuclide release becomes excessive, the plant is shut down and the tube repaired.

5. A steam line break, happening outside the containment vessel and upstream of the isolation valve, results in the loss of the secondary coolant. If there is primary to secondary leakage, radionuclides are released within the plant space and thus to atmosphere.

6. A complete loss of all the fission products to the sea is not a credible accident, because dual safeguard systems are used to keep the core subcritical and to remove the decay heat. The possibility of a core meltdown occurring from simultaneous failure of two independent safeguard systems is not a credible accident.

References

1. United States Atomic Energy Commission, Rules and Regulations, Title 10, Code of Federal Regulations, Part 20.

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3. "Preliminary Safety Analysis Report, Trojan Nuclear Plant," Portland General Electric Company, Docket 50-344.

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NONTHERMAL, NONRADIOACTIVE LIQUID WASTES

The wastes that will be produced by the presence of people in the underwater power station were estimated on the basis of available design data. The nonradioactive, nonthermal liquid wastes would consist of effluent from the galley, showers and lavatories, laundry, toilet facilities, and from miscellaneous laboratory and industrial facilities. The quantity and concentration of wastes from these sources will vary with the number of people required to operate the plant, and their scheduled stay at the power station. Environmental differences, operating schedules, and transportation arrangements might alter the quantity and composition of wastes from one power station site to another. Since it was necessary to estimate reasonable waste quantities representative of all potential sites, the data below are presented on a unit basis so that estimates can be scaled up or down to approximate the actual conditions.

Based on operating requirements of similar shore-based power stations, and of offshore installations such as oil-well platforms, the personnel were estimated as 50 full-time residents. Pollutant quantities were taken from the high end of various ranges reported in the literature, to account for the expected predominance of adult male inhabitants, rather than a composite of both sexes and all ages.

Wastes

Table 9 presents the volume of liquid wastes and concentration of pollutants from each source, and aggregate values for the composite waste stream.

Toilet wastes represent the major nonthermal, nonradioactive pollutant from the power station. The organic load added through the toilets was estimated from medical studies performed for the aerospace industry, and from measurements of household waste effluents from apartment buildings and separate homes. The volume of the toilet wastes will depend on the amount of flushing water used by the toilets. If standard toilets are used, the volume will be approximately 5 gallons per flushing, and an average of 5 to 6 flushings per man-day is expected.

The galley was assumed to have full capabilities for food preparation, garbage disposal, and dishwashing, to serve the full complement of the power

Table 9. Estimated Volume of Liquid Wastes and Concentration of Pollutants

Source	One Man Per Day	50 Men Per Day	Percent of Total	Concentration	Percent Removable by Filtration
Toilets	95.0 l	4,750 l	42%	--	--
Ultimate BOD	73.0 g	3,650 g	57%	770 mg/l	30%
Nitrogen	9.0	450	90	95	40
Phosphorus	1.4	70	46	15	30
Galley wastes	51.0 l	2,550 l	23%	--	--
Ultimate BOD*	44.0 g	2,200 g	35%	863 mg/l	10%
Nitrogen	0.3	15	3	6	25
Phosphorus	0.6	30	20	12	8
Showers and lavatories	75.0 l	3,750 l	33%	--	--
Ultimate BOD	6.8 g	340 g	5%	91 mg/l	11%
Nitrogen	0.6	30	6	8	23
Phosphorus	0.35	17.5	11	5	9
Laundry	4.7 l	235 l	2%	--	--
Ultimate BOD	4.0 g	200 g	3%	850 mg/l	13%
Nitrogen	0.1	5	1	21	19
Phosphorus	0.7	35	23	149	3
Total wastes	225.7 l	11,285 l	100%	--	--
Ultimate BOD	127.8	6,390 g	100%	565 mg/l	21%
Nitrogen	10.0	500	100	44	38
Phosphorus	3.0	152	100	13	17

*Includes 5 to 10 gram/capita of grease. BOD: biochemical oxygen demand.

station. It was assumed that a garbage grinder would be used. The principal components of the galley wastes will be soil, grit (bones, egg shells, glass and metal chips, etc.), food particles, grease, and cleaning compounds for dishes and utensils. Such wastes rapidly decay to produce offensive odors and degrade water quality. Generally, low concentrations of pathogenic bacteria would be expected; however, relatively high concentrations of fecal-type coliforms have been detected on occasion.

The wastes from the shower and lavatory can contain countless different substances, but will consist primarily of body soil, and various ointments and body cleansers, such as soap, toothpaste, and shampoo. The total pollution load is not expected to be high; however, there will be substantial amounts of nitrogen and phosphorus from the cleansers. There is a minor possibility of disease bacteria surviving in the effluent.

The volume of the laundry wastes will depend to a great extent on the time spent by personnel at the station, and the types of services supplied to them. Duty periods at the power station probably would not exceed two weeks, and it seems reasonable to assume that most laundering would be done ashore. About half the usual figures for laundry volume and pollutants were used in the estimate. In general, pollutants in laundry wastes will be few, and bacteria will be controlled by the bactericidal effects of cleaning compounds, bleaches, and hot water.

Laboratory and industrial wastes would normally occur in very small quantities, which could be treated or disposed of separately from the sewage wastes. For example, strong acids or bases should be neutralized before disposal. Biological poisons and other harmful chemicals can be destroyed or contained for disposal on shore.

The effect of the quality of the added water (for example the water used for toilet flushing) was not considered. However, the concentrations of the major pollutants considered in this analysis are dilute in most natural waters, including sea water, and the estimated values should be valid.

Waste Disposal

The quantity of wastes is very small. A few calculations readily show that the dispersal of the effluent into only 3000 cubic meters of sea water (equivalent to, say, a vertical cylinder about 23 ft in diameter for a plant situated in 250 ft of water) would reduce the BOD concentration to 2 mg per liter, the nitrogen to less than 0.2 mg/l and the phosphorus to less than 0.05 mg/l. Thus, unless the power station were located in an area of essentially no circulation, the small quantities of wastes discharged into the open sea would be assimilated by marine organisms without detriment. Dispersal could be enhanced by finely grinding all solids in the wastes, and discharging the wastes into the cooling water effluent plume.

The discharge of all wastes without treatment would be the easiest and most economical method of waste disposal. If it becomes necessary to do so, there are methods within present technology for treating the wastes before discharge. Methods that would not entail a severe cost burden include: filtration of solid materials and discharge of the clear filtrate; secondary treatment of all wastes, with discharge of the treated effluent; and secondary treatment of all toilet and galley wastes only, the remaining wastes being discharged without treatment.

Filtration, as shown by table 9, would remove slightly more than one-fifth of the pollutional load, including most of the aesthetically objectionable material. The substances removed would, however, then have to be disposed of. Incineration would require additional equipment, maintenance, and supervision. Disposal ashore would require special storage and handling facilities.

A system for secondary treatment of all wastes could be provided in the power station at moderate expense. The major portion of potential pollutants produced by the power plant could be eliminated at less cost by treating just the toilet and galley wastes. These wastes contain an estimated 92% of the ultimate BOD, 93% of the nitrogen compounds, and 66% of the phosphorus compounds, suspended in 65% of the total liquid volume. Toilet and galley wastes are also the major source of pathogenic bacteria. Thus, separation of the waste streams would permit the use of a more compact and more efficient waste treatment system.

Of the systems of waste treatment that are commercially available today, probably the best suited for the offshore power plant would be an extended aeration biological system. Extended aeration treatment is widely used by many small municipalities and all kinds of industries. Its use has grown rapidly because of its reliable, low-maintenance performance on a wide variety of wastes. In addition to domestic sewage, these wastes include petroleum compounds, phenols, organic processing wastes, and even wastes containing toxic substances such as heavy metals, cyanides, and pesticides. The method is readily adaptable to differences in salinity, and thus would operate efficiently if sea water were used for flushing toilets, etc. It is doubtful that anything liable to enter the power plant's sewage stream would seriously impair the operation of such a system. Little attention to extended aeration plants is usually required and, since they operate as biological incinerators, disposal of sludge is minimized.

Figure 6 is a schematic of the extended aeration system of waste treatment. The raw waste enters the aerated reactor where it is mixed with a culture of aerobic bacteria acclimated to the digestion of sewage. The bacterial particles rapidly absorb the waste particles and soluble nutrients from the waste and use it for energy and the synthesis of new cells. The sewage is retained in the aeration chamber for a relatively long (18- to 30-hour) period of aera-

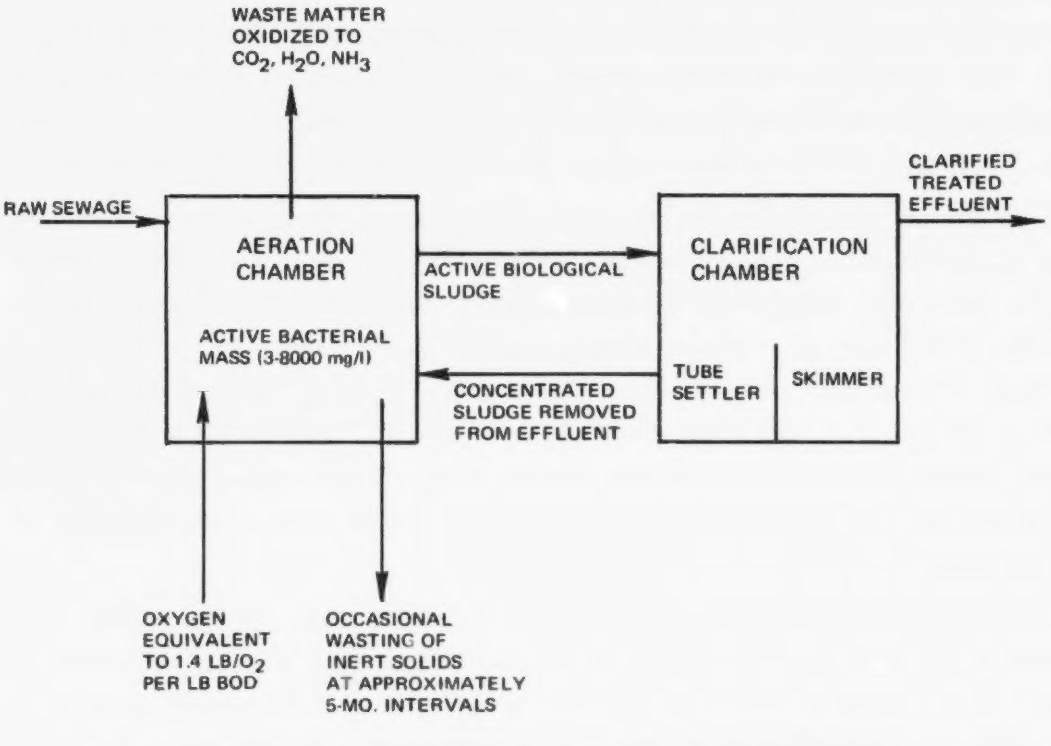
WASTE MATTER OXIDIZED TO CO_2, H_2O, NH_3
RAW SEWAGE
AERATION CHAMBER
ACTIVE BACTERIAL MASS (3-8000 mg/l)
ACTIVE BIOLOGICAL SLUDGE
CLARIFICATION CHAMBER
CLARIFIED TREATED EFFLUENT
TUBE SETTLER
SKIMMER
CONCENTRATED SLUDGE REMOVED FROM EFFLUENT
OXYGEN EQUIVALENT TO 1.4 LB/O_2 PER LB BOD
OCCASIONAL WASTING OF INERT SOLIDS AT APPROXIMATELY 5-MO. INTERVALS

Figure 6. Extended Aeration Sewage Treatment

tion, which keeps the culture in a state of endogenous respiration. This means that, because of insufficient food, excess bacterial cells are themselves being broken down and oxidized. This condition also promotes the rapid absorption of nutrients from the entering waste. The liquid is thus rapidly depleted of nutrient matter, and treated effluent is obtained simply by separating the solid matter (flocculated bacterial cells) from the liquid. Although positive clarification methods such as filtration and membrane separation are available, gravity separation is generally more economical and is considered appropriate for this case. Innovations such as the slanted tube clarifier greatly improve gravity separation efficiency and are available from several manufacturers. Floatable solids that do not settle are removed by a skimming device (which is standard on most commercial units), before the effluent is discharged. The solids which settle from the effluent and which are removed by the skimmer are returned to the aeration chamber to be further oxidized, with the eventual products being water, carbon dioxide, and ammonia. Combined with the loss of small quantities of floating, highly oxidized sludge in the effluent, the self-oxidation of excess bacterial cells nearly eliminates the need for separate solids wasting. The only solids removal required is the periodic disposal of mineral matter such as grit and metal and some highly resistant organic materials. If required by local conditions and laws, refinements such as effluent filtration and disinfection are commercially available. Additional equipment for the removal of phosphate is also obtainable, but in most cases the additional cost and operational difficulty would not be warranted by the small quantities of phosphate discharged in the power station sewage. A complete system for all of the power plant's sewage and similar wastes would occupy about 750 cubic feet of space and consume about 16 kw of power. Figure 7 shows a typical equipment arrangement.

Conclusions and Recommendations

Except in very unusual environs, a power station in the open sea would create no pollution of consequence from the nonthermal, nonradioactive liquid wastes. Thus, direct discharge of these wastes into the sea would be acceptable. Dispersion of the wastes might be promoted by directing the waste discharge into the cooling water effluent plume to increase mixing and circulation. Grinding of the wastes would overcome aesthetic objections, and reduce the possibility of sludge accumulations.

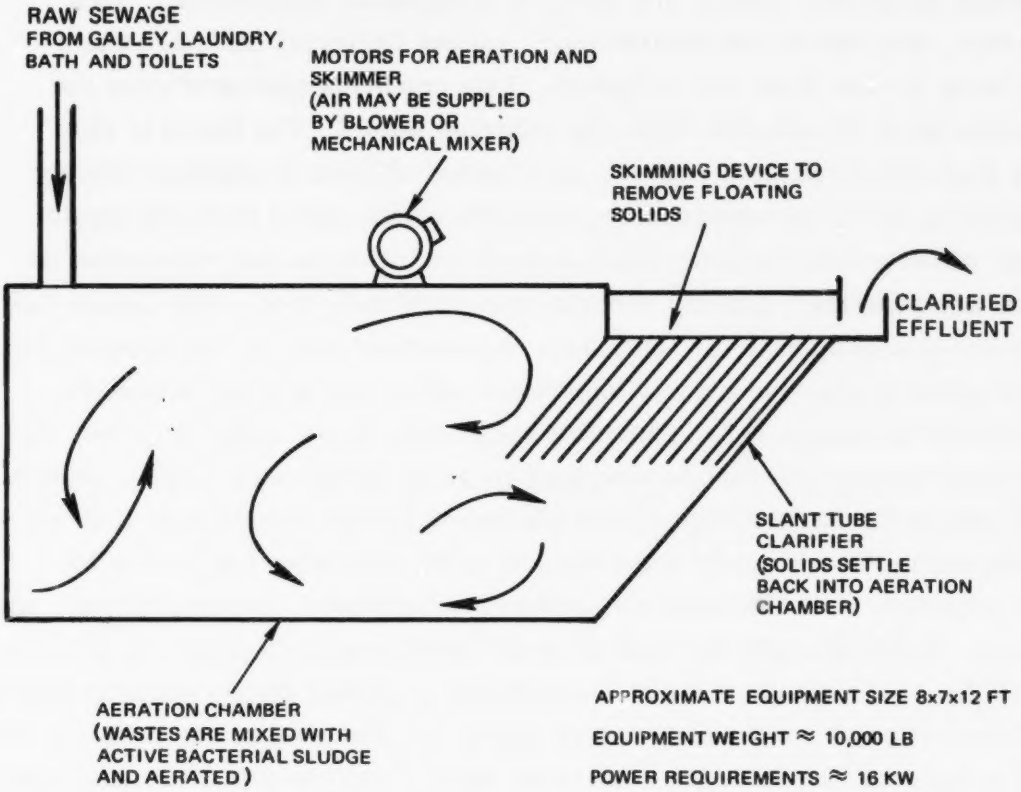
RAW SEWAGE
FROM GALLEY, LAUNDRY, BATH AND TOILETS
MOTORS FOR AERATION AND SKIMMER (AIR MAY BE SUPPLIED BY BLOWER OR MECHANICAL MIXER)
SKIMMING DEVICE TO REMOVE FLOATING SOLIDS
CLARIFIED EFFLUENT
SLANT TUBE CLARIFIER (SOLIDS SETTLE BACK INTO AERATION CHAMBER)
AERATION CHAMBER (WASTES ARE MIXED WITH ACTIVE BACTERIAL SLUDGE AND AERATED)
APPROXIMATE EQUIPMENT SIZE 8x7x12 FT
EQUIPMENT WEIGHT ≈ 10,000 LB
POWER REQUIREMENTS ≈ 16 KW

Figure 7. Extended Aeration Equipment

There might be offshore areas where such unrestricted waste discharge would be impermissible. Such cases are more probable where power stations are within restricted waters, and treatment is required for all sewage. (Public Law 91-224, The Water Quality Improvement Act of 1970, requires treatment of wastes from all vessels in navigable waters. Conceivably, this requirement might be extended to fixed structures such as the power station, even if they were in open water.)

Extended aeration treatment of the wastes would be sufficient to meet all requirements and would be relatively economical to install and operate. Where possible, waste segregation to treat only galley and toilet wastes would allow pollution control at reduced installation and operating costs.

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Section 5
THERMAL DIFFUSION ANALYSIS

In this section, the thermal field resulting from the discharge of a nuclear power plant's condenser cooling water is predicted for each of the four sites under consideration.

The basic investigation concerns a buoyant, turbulent jet discharging into a fluid with a free surface, density stratification, and currents. Some of these aspects are not adequately treated in the literature, but a more detailed study than the present one will be required to correct these deficiencies. The basic procedure used here, therefore, is to adapt existing methods of investigation, and to make engineering assumptions as required. In this connection, one function of the study is to identify areas in which further work is necessary.

BACKGROUND

A literature search was made for methods of predicting the thermal field. This search was greatly facilitated by the work of Parker and Krenkel (25)*, in which various aspects of thermal pollution are discussed and a comprehensive list of references presented. Other studies of a general nature were consulted (3, 4, 8, 9, 16, 18, 21, 25, 26, 29, 30, 31, 32, 33, 34). The primary emphasis in the literature search was to find information that dealt with elements intrinsic in the offshore case; i.e., relatively deep water, density stratification, and ocean currents. The basic problem was formulated as one of discharge from a single jet. This model was chosen for simplicity, and because the results can be applied to a diffuser with many jets, as long as the spacing is such that interference does not occur. With this basic model, the thermal field is defined by the temperature distribution in the buoyant jet. Ideally, therefore, the goal of the study is to characterize a buoyant jet discharging into a fluid of finite depth with density stratification and a current.

Among the work dealing with a buoyant jet (1,2, 11, 12, 13, 17, 22, 23, 24), is the fundamental integral approach of Morton et al (23), which is the basis for all recent analysis, and the work of Abraham (1), who considers buoy-

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*Numbers in parenthesis indicate references listed on page 99 ff.

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ancy forces within the zone of flow establishment. The effect of a free surface is investigated to some extent by Hart (17), and in the experimental work of Frankel and Cumming (13). The buoyant jet in a stratified fluid is discussed by many authors (7, 11, 12, 14, 17, 28); however, the state of the art is best exemplified by the work of Fan (11, 12), who also considers a cross flow and various angles of discharge. The effect of a current is also considered by many authors (6, 10, 11, 12, 19, 35, 36); however, again the work of Fan (11, 12) is the most comprehensive.

To sum up, methods are available in the literature for predicting the thermal field for the basic model of a single jet discharging into an infinite body of fluid. There is, however, a notable lack of analytical methods and experimental data that apply to a buoyant jet in a finite body of fluid (one with a free surface). The treatment of density stratification appears to be adequate, but the work on currents is not sufficiently general.

THE BASIC MODEL

Coastal and riverside nuclear power plant installations normally require large, expensive diffuser systems to meet existing standards for thermal discharge. These systems are necessary because of the relatively shallow receiving water (usually less than 20 feet deep). This situation is not encountered with an offshore station discharging at a depth of about 250 feet, therefore a basic model of a single point discharge is chosen. If the resulting thermal field is acceptable from an ecological viewpoint, no further optimization need be carried out. For the power plant operating conditions described in section 4, a discharge diameter of 15 feet gives a reasonable velocity of 7.65 ft/sec. Also, from section 4, the temperature rise across the condenser is taken to be 25°F and is independent of the temperature at the condenser inlet. Compared with a buoyant vertical jet, a horizontal one undergoes greater dilution and thus greater cooling on its way to the surface. For these reasons the basic model chosen is a horizontal, buoyant, turbulent jet with the following initial conditions:

$u_o = 7.65$ ft/sec

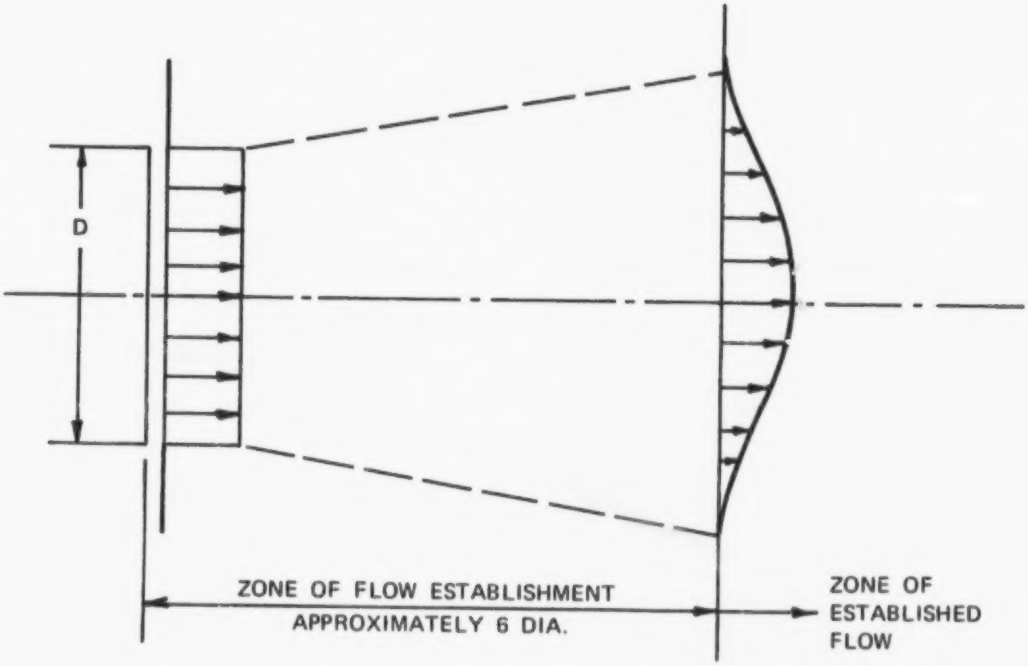
$D = 15$ ft

$t_o - t_{oa} = 25^{o}$F

where the subscripts o and oa indicate conditions in the jet at the point of discharge, and in the receiving water at the discharge depth respectively. All notation is defined under Nomenclature at the end of this section. It is assumed that the condenser discharge is sufficiently removed from the ocean floor to eliminate interaction between the jet and the bottom.

THE BUOYANT JET IN A STRATIFIED INFINITE FLUID

The present level of development in the treatment of buoyant jets in an infinite fluid is reflected in the work of Fan (11), who considers a variable discharge angle, density stratification, and cross currents. Fan's work deals primarily with the zone of established flow, which is defined as the region in which the velocity and temperature distribution can be characterized by a gaussian profile. This profile is not fully established until the jet is about six diameters downstream from the point of origin. In this region, called the zone of flow establishment, the velocity and temperature distributions are changing from the "top hat" profiles at the point of discharge to the gaussian distribution in the zone of established flow as shown in the following sketch.



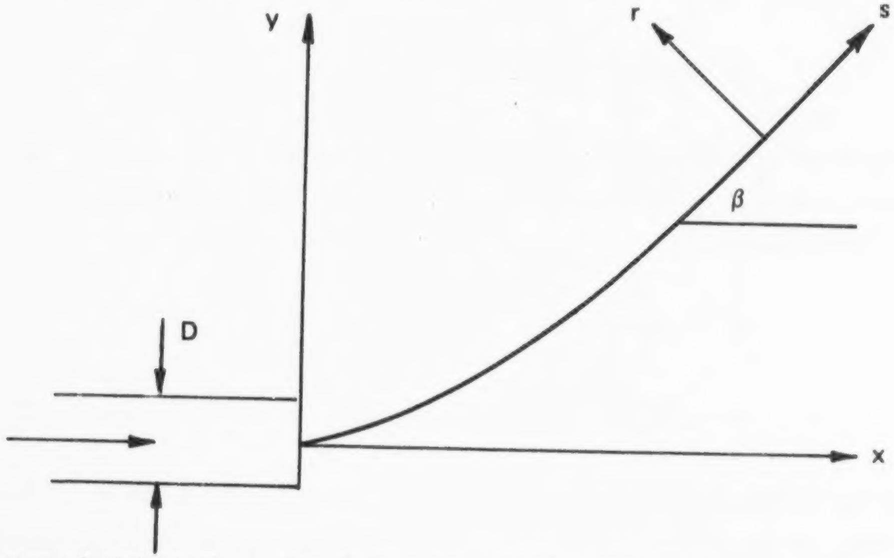
Fan assigns to this region a correction factor of 6.2 diameters, a figure obtained from the work of Albertson et al (2). This is adequate for most applications; however, because of the 15 ft discharge diameter, the zone of flow establishment is extensive in this case and will be further investigated.

The Zone of Flow Establishment

The most comprehensive treatment of the zone of flow establishment is presented by Abraham (1), who includes buoyancy in his analysis. Though thermal stratification is neglected, it should not be important in this zone. The buoyancy effect is especially significant at the low densimetric Froude number which is obtained with the basic model. The Froude number, which appears later in the governing equations, is dimensionless and indicates the relative importance of momentum and buoyancy effects in a jet. A momentum jet has a large Froude number, and a buoyant jet a low one.

The working results of Abraham, and most authors, are presented primarily for large values of both the Froude number and the dimensionless distance from the point of discharge. For our basic model, results are required for relatively low values of the Froude number, and a vertical distance from the point of discharge of less than 20 diameters. Because of this, the results presented by Abraham cannot be used directly, and his basic equations must be solved for values in the region of interest.

The geometry and coordinate system shown below, and the subsequent analysis, are taken directly from Abraham's report, except that temperature has been substituted for concentration.



The above sketch defines the dimensional coordinates x, y, s, r, and the inclination angle β. In the subsequent work it will be convenient to use the dimensionless coordinates defined below:

$$X = x/D$$
$$Y = y/D$$
$$S = s/D$$
$$R = r/D$$

where D is the diameter of the discharge pipe.

In addition, the following dimensionless velocity, temperature, and density are defined as:

$$U = u/u_o$$

$$T = \frac{t-t_{oa}}{t_o-t_{oa}}$$

$$P = \frac{\rho_{oa}-\rho}{\rho_{oa}-\rho_o}$$

Whenever possible, lower case letters are used to indicate dimensional quantities and upper case letters to denote dimensionless quantities.

At the end of the zone of flow establishment the gaussian distributions of both velocity and temperature are given by Abraham as:

$$\bar{U}(R,S) = U_c(S)e^{-k(R/S)^2} \tag{1}$$

$$\bar{T}(R,S) = T_c(S)e^{-\mu k(R/S)^2} \tag{2}$$

where the subscript c denotes conditions at the jet centerline, and the bar over a quantity indicates a function of both R and S. The quantities μ and k are local variables given by:

$$k = -304\left(\frac{\beta}{\pi}\right)^3 + 228\left(\frac{\beta}{\pi}\right)^2 + 77 \tag{3}$$

$$\mu = 0.96\left(\frac{\beta}{\pi}\right)^3 - 0.72\left(\frac{\beta}{\pi}\right)^2 + 0.80 \tag{4}$$

In the zone of flow establishment, the flow is in the transition between the "top hat" profile at the point of discharge and the gaussian profile given above. In this region, Abraham uses the results of Albertson et al (2), to obtain the following equation:

$$\tan\beta = \frac{S}{F^2}\left[1 + \frac{1}{4}\left(\frac{S}{S_e}\right) + \frac{1}{6}\left(\frac{S}{S_e}\right)^2\right] \qquad (5)$$

where F is the Froude number and S_e is the dimensionless centerline length at the end of the zone of flow establishment.

The Froude number, discussed previously, is given by:

$$F = \frac{u_o}{\sqrt{Dg\left(\frac{\rho_{ao} - \rho_o}{\rho_o}\right)}}$$

where all quantities have been defined except g, which is the gravitational constant.

When applied at $S = S_e$, equation (5) yields:

$$\tan\beta_e = \frac{S_e}{F^2}\left[1 + \frac{1}{4} + \frac{1}{6}\right] \qquad (6)$$

Another expression relating S_e and β_e is obtained from the continuity equation as:

$$S_e{}^2 = \frac{k\,(1+\mu)^2}{8}\cos\beta_e \qquad (7)$$

Equations (6) and (7) were solved for S_e and β_e as a function of F, resulting in the curves of figures 8 and 9. From geometry, it is apparent that $dX/dS = \cos\beta$ and $dY/dS = \sin\beta$, so that the coordinates of the jet centerline are given by:

$$X = \int_0^S \cos\beta\ d\,S \qquad (8)$$

$$Y = \int_0^S \sin\beta\ d\,S \qquad (9)$$

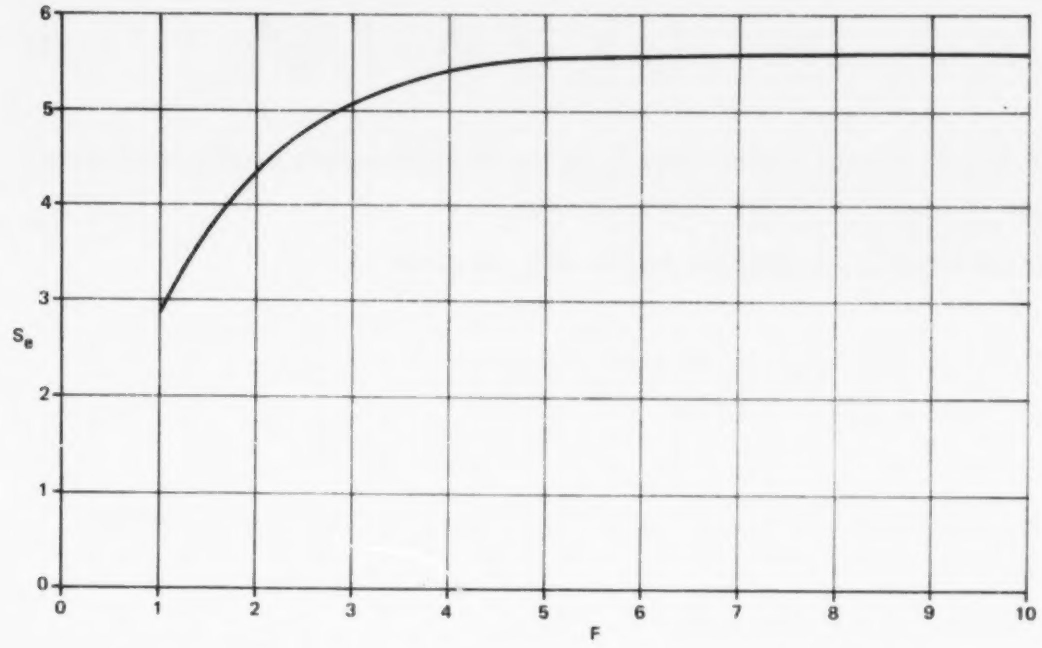


Figure 8. Dimensionless Length of the Zone of Flow Establishment vs Froude Number

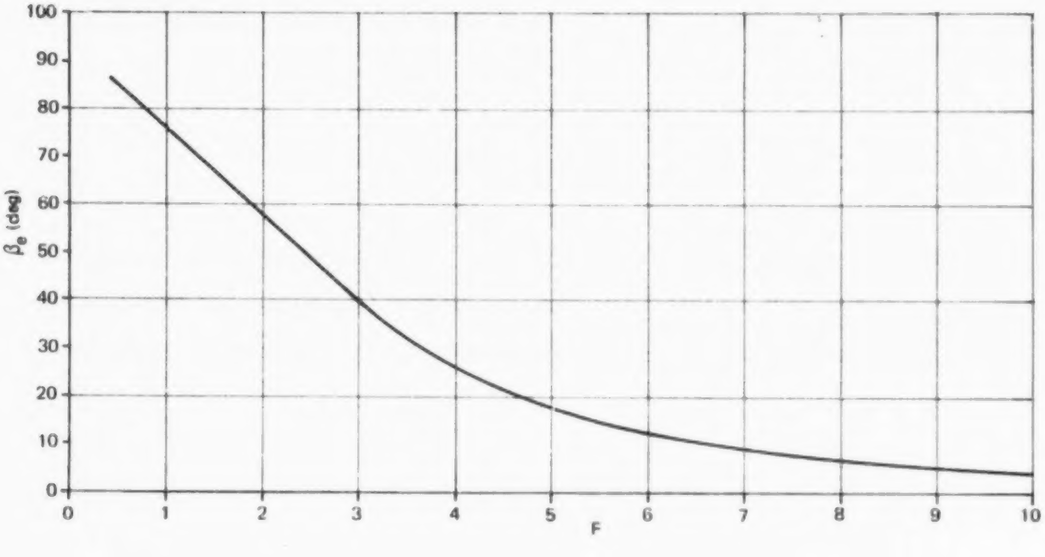


Figure 9. Deflection of the Jet Centerline at the End of the Zone of Flow Establishment vs Froude Number

While the integrations cannot be carried out in closed form, equations (8) and (9) were evaluated numerically on a digital computer, using equation (5) to evaluate the integrand. The results are plotted in figure 10 for several values of the Froude number. From figure 10, it can be seen that for low values of F, there is a significant jet deflection in the zone of flow establishment. This deflection would have been neglected if Abraham's method had not been used for this zone. The results presented in figures 8, 9, and 10 are used as initial conditions for the more general approach of Fan in the zone of established flow.

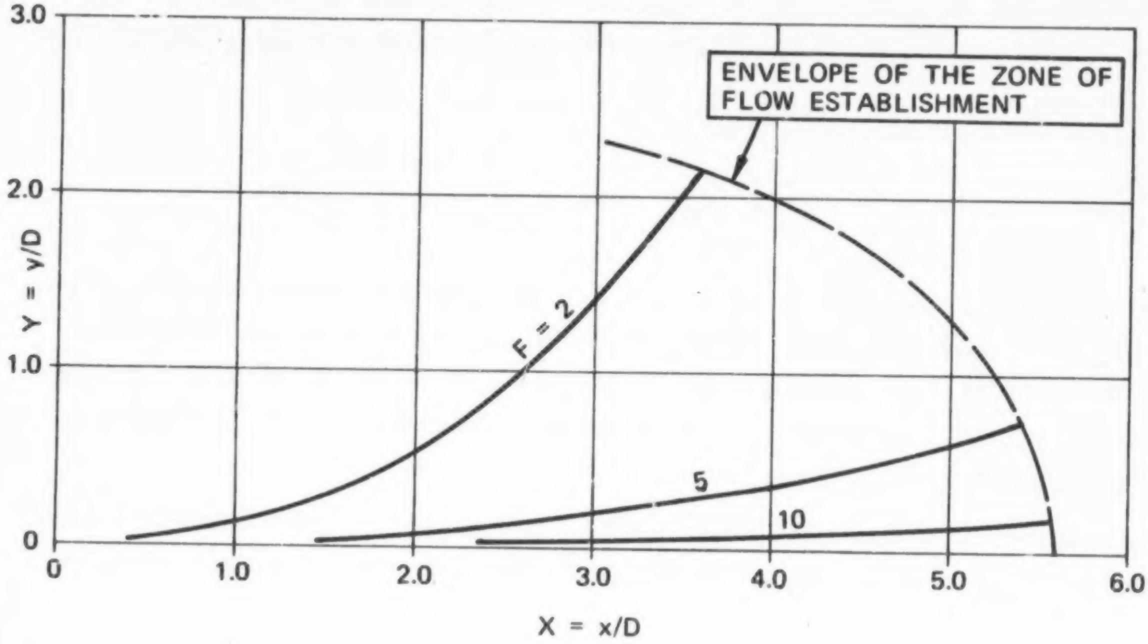


Figure 10. Jet Centerline Path in the Zone of Flow Establishment for Various Froude Numbers

The Zone of Established Flow

In this region, the method of Fan (11) is used to predict the thermal field from a horizontal buoyant jet. The basic difference between the approach of Fan and that of Abraham is in the assumed form of the velocity and density or temperature distributions. Fan assumes the following form:

$$\bar{u}(r,s) = u_c(s)\, e^{-(r/b)^2} \qquad (10)$$

$$\frac{\rho_a(s) - \bar{\rho}(r,s)}{\rho_o} = \left[\frac{\rho_a(s) - \rho(s)}{\rho_o}\right] e^{-(r/\lambda b)^2} \qquad (11)$$

where b is a function of the centerline distance s, and ρ_a, the ambient water density, can be a function of y, and, therefore, also of s. The parameter λ is the turbulent Schmidt number, and is taken to be 1.16 for a round, buoyant jet. A comparison of equations (1) and (2) with equations (10) and (11) indicates that the distribution of Fan and Abraham are equivalent if:

$$b^2 = s^2/k$$

and

$$\lambda^2 = 1/\mu$$

In Abraham's method, μ and k, as given by equations (3) and (4), are empirically determined functions written explicitly in terms of the jet centerline inclination angle β, and, therefore, implicitly in terms of the centerline distance s. In Fan's method, b is an unknown function of s and becomes a dependent variable in the problem.

In addition to the gaussian distributions given above, the fundamental premise in Fan's method is that the entrainment rate along the jet path is given by:

$$\frac{dQ}{ds} = 2\pi\alpha\, u_c\, b \qquad (12)$$

where Q is the flow rate in ft^3/sec and α is the entrainment coefficient which is taken as 0.082 for a round jet. Using these expressions, the governing equations are obtained by applying the principle of conservation of mass, momentum, and density, resulting in the following equations as taken directly from Ditmars (7).

$$\frac{du_c}{ds} = \frac{2g\lambda^2}{u_c}\left[\frac{\rho_a - \rho}{\rho_o}\right]\sin\beta - \frac{2u_c\,\alpha}{b} \tag{13}$$

$$\frac{db}{ds} = 2\alpha - \frac{bg\lambda^2}{u_c^{\,2}}\left[\frac{\rho_a - \rho}{\rho_o}\right]\sin\beta \tag{14}$$

$$\frac{d\beta}{ds} = \frac{2g\lambda^2}{u_c^{\,2}}\left[\frac{\rho_a - \rho}{\rho_o}\right]\cos\beta \tag{15}$$

$$\frac{d}{ds}(\rho_a - \rho) = \frac{1+\lambda^2}{\lambda^2}\left[\frac{d\rho_a}{dy}\right]\sin\beta - \frac{2\alpha}{b}(\rho_a - \rho) \tag{16}$$

In addition there are the geometrical relations:

$$\frac{dx}{ds} = \cos\beta \tag{17}$$

$$\frac{dy}{ds} = \sin\beta \tag{18}$$

The above system of coupled, nonlinear, ordinary differential equations is sufficient to completely determine the path of the jet when ρ_a is specified as a function of y.

The primary quantity of interest is the thermal field, which cannot be obtained directly from the above system of equations. The temperature and density are not simply related, because the salinity and depth also affect the density. For this reason, another equation is required to account for the temperature. This additional expression is obtained from the conservation of energy law which can be written as:

$$2\pi\frac{d}{ds}\left[\int_0^\infty \bar{u}\,(\bar{t}-t_{oa})r\,dr\right] = (t_a - t_{oa})\frac{dQ}{ds} = 2\pi\alpha\, u_c\, b\,(t_a - t_{oa}) \tag{19}$$

where equation (12) is used for the entrainment rate.

As in equation (11), a gaussian temperature distribution is assumed with respect to the ambient temperature:

$$\frac{\bar{t}(r,s) - t_a(s)}{t_o - t_{oa}} = \left[\frac{t_c(s) - t_a(s)}{t_o - t_{oa}}\right] e^{-(r/\lambda b)^2} \tag{20}$$

The above equation can be written in terms of dimensionless temperature as:

$$\bar{T}(r,s) - T_a(s) = \left[T_c(s) - T_a(s)\right] e^{-(r/\lambda b)^2} \tag{21}$$

Writing equation (19) in terms of dimensionless temperature yields:

$$\frac{d}{ds}\left[\int_o^\infty \bar{u}\left[T_a + (T_c - T_a)e^{-(r/\lambda b)^2}\right] rdr\right] = \alpha u_c b T_a \tag{22}$$

Using equation (10), and carrying out the integration, gives:

$$\frac{d}{ds}\left[\frac{u_c b^2}{2}\left(T_a + \frac{\lambda^2}{1+\lambda^2}\left[T_c - T_a\right]\right)\right] = \alpha b u_c T_a \tag{23}$$

The basic form of the continuity equation, before being rearranged and combined to give equation (13), was:

$$\frac{d}{ds}\left[\frac{u_c b^2}{2}\right] = \alpha u_c b \tag{24}$$

Equations (18), (23), and (24), can be combined to yield:

$$\frac{dT_c}{ds} = -\frac{2\alpha}{b}(T_c - T_a) - \frac{1}{\lambda^2}\frac{dT_a}{dy}\sin\beta \tag{25}$$

which is the required additional expression.

The governing equations are now rewritten in terms of dimensionless quantities defined previously, and the dimensionless variable B, where B = b/D:

$$\frac{dU_c}{dS} = \frac{2\lambda^2}{U_c F^2}(P - P_a)\sin\beta - \frac{2\alpha U_c}{B} \tag{26}$$

$$\frac{dB}{dS} = 2\alpha - \frac{B\lambda^2}{U_c^2 F^2}(P - P_a)\sin\beta \tag{27}$$

$$\frac{d\beta}{dS} = \frac{2\lambda^2}{U_c^2 F^2}(P - P_a)\cos\beta \tag{28}$$

$$\frac{dP}{dS} = -\frac{2\alpha}{B}(P - P_a) - \frac{1}{\lambda^2}\frac{dP_a}{dY}\sin\beta \tag{29}$$

$$\frac{dT_c}{dS} = -\frac{2\alpha}{B}(T_c - T_a) - \frac{1}{\lambda^2}\frac{dT_a}{dY}\sin\beta \tag{30}$$

$$\frac{dX}{dS} = \cos\beta \tag{31}$$

$$\frac{dY}{dS} = \sin\beta \tag{32}$$

This system of equations must be solved by numerical integration on a digital computer. It represents the solution for the thermal and flow fields from a turbulent, buoyant jet discharging into an infinite body of fluid that has arbitrary density and temperature stratification.

Before the governing equations can be integrated, initial conditions are required for the variables X, Y, S, U, T, P, B, and β. Some of these values can be obtained from figures 8, 9, and 10, which give the conditions at the end of the zone of flow establishment, and, therefore, at the beginning of the zone of established flow.

Although the Froude number changes from site to site, a nominal value of $F = 5$ is chosen to obtain the initial conditions from figures 8, 9, and 10 as given below:

Figure 8 $S_e = 5.5$

Figure 9 $\beta_e = 17.5^o = 0.305$ radians

$$\text{Figure 10} \begin{cases} X_e = 5.4 \\ Y_e = .75 \end{cases}$$

where the subscript e indicates the end of the zone of flow establishment.

A problem arises in determining B_e, because this quantity does not exist in Abraham's approach. However, the velocity distributions should be identical at the junction of the two zones and, as discussed previously, this occurs when $b^2 = s^2/k$ or $B_e = S_e/\sqrt{k_e}$. The value of k_e can be computed from equation (3) with $\beta = \beta_e = 0.305$ radians.

Carrying out the computation gives:

$$k_e = 78.87$$

and

$$B_e = \frac{5.55}{\sqrt{78.87}} = .624$$

The other required initial values are, by definition:

$$U_c = 1, \quad P = 1, \quad T_c = 1$$

With these initial conditions, equations (26) through (32) are integrated numerically on a digital computer, using the simple Taylor series expansion such as:

$$T_c \Big|_{S+\Delta S} = T_c \Big|_S + \frac{dT_c}{dS}\Big|_S \Delta S$$

The equation of an isotherm can be obtained by setting $\overline{T}(S,R)$ equal to γ, a constant, in equation (21), thus yielding:

$$\frac{\gamma - T_a}{T_c - T_a} = e^{-(R_\gamma / \lambda B)^2}$$

or

$$R_\gamma = \lambda B \left[\ln \left(\frac{T_c - T_a}{\gamma - T_a} \right) \right]^{\frac{1}{2}} \tag{33}$$

R_γ is the radius at which the local temperature $\bar{T}$ equals a constant, γ. This equation must be solved in conjunction with equations (26) through (32)

When the centerline temperature T_c equals γ, the radius goes to zero and the isotherm forms a closed surface. The volume of water within this surface is of interest and can be computed from:

$$v = v_e + \pi \int_{s_e}^{s_\gamma} r_\gamma^2 \, ds$$

where

v_e = volume of the zone of flow establishment

s_e = jet centerline distance at the beginning of the zone of established flow

s_γ = jet centerline distance where r_γ goes to zero.

Defining a dimensionless volume as $V = v/D^3$, and assuming that the volume of the zone of flow establishment is $v_e = [\pi/4] D^2 s_e$, so that $V_e = [\pi/4] S_e = 4.32$, the above expression can be written as:

$$V = 4.32 + \pi \int_{5.5}^{S_\gamma} R_\gamma^2 \, dS \tag{34}$$

This integration was also carried out on the digital computer.

As far as temperature rise is concerned, the ambient water most affected by the nuclear power plant is that passing through the condenser. Also affected, of course, is the ambient water entrained by the discharge jet. For these reasons, the jet flow rate is a quantity of interest and is expressed by:

$$Q = 2\pi \int_{0}^{\infty} \bar{u}\, r\, d\, r$$

With the condenser discharge Q_o given by:

$$Q_o = \frac{\pi}{4} D^2 u_o$$

the flow rate ratio is:

$$\frac{Q}{Q_o} = 8 \int_{0}^{\infty} U\, R\, d\, R$$

Using equation (10), and carrying out the integration, yields:

$$\frac{Q}{Q_o} = 4\, U_c\, B^2 \qquad (35)$$

so that the flow rate can be determined from a simple additional computation. Another important quantity is the mean jet temperature, t_m, which is given by:

$$t_m = \frac{2\pi}{Q} \int_{0}^{\infty} \bar{u}\, \bar{t}\, r\, d\, r$$

Using equations (10), (20), and (35), the integration yields:

$$\frac{t_m - t_a}{t_c - t_a} = \frac{\lambda^2}{1 + \lambda^2} = 0.573$$

or, in dimensionless form

$$\frac{T_m - T_a}{T_c - T_a} = 0.573 \qquad (36)$$

With T_a available from the initial conditions, and T_c determined from computer results, the mean jet temperature can easily be computed.

Finally, the time-temperature history of the water, and, therefore, of the entrained organisms that travel through the condenser and into the jet, are of interest. In the condenser, it can be assumed that the temperature increases linearly as the water passes through the tubing at a constant velocity. A velocity of 9 ft/sec and 100 ft of condenser tubing, are also assumed. Through the condenser, the water temperature is increased by 25°F in 11 seconds. The discharge duct is taken to be 100 ft of 15-ft diameter pipe, and the discharge velocity, 7.65 ft/sec. In this region, the temperature increase remains constant at 25°F for 13 seconds. Turbulent flow results in relatively uniform velocity and temperature profiles, so that it may be assumed that all the water going through the condenser is subjected to the conditions given above. In the jet, organisms have different time-temperature histories, depending on their location with respect to the centerline. However, those organisms on the centerline are subjected to the highest temperature for the longest period of time, and are of primary interest. In the zone of flow establishment, the centerline velocity is a constant at 7.65 ft/sec over the dimensionless length of $S_e = 5.5$ (page 70), or $s = 82$ ft for a 15-ft diameter pipe. In this region, the temperature rise remains at 25°F for 11 seconds.

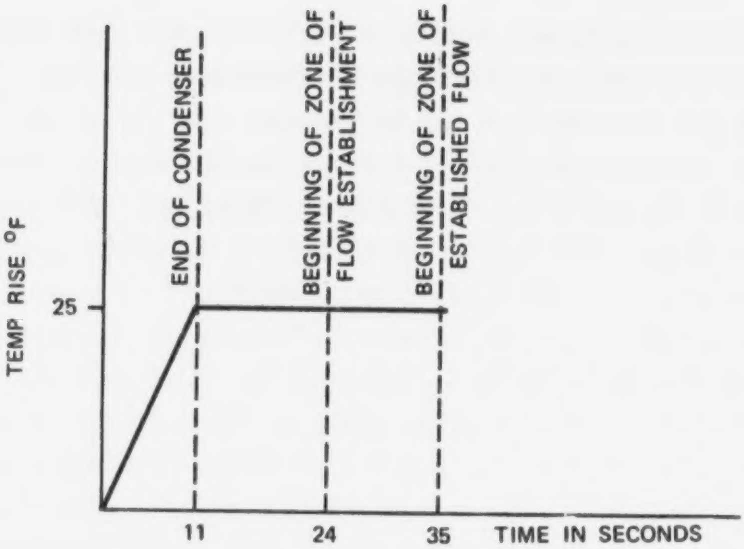
In the zone of established flow, the centerline velocity and temperature are part of the general solution. The time in the zone of established flow is given by:

$$\eta = \int_{s_e}^{s} \frac{ds}{u_c}$$

or, in dimensionless form:

$$\eta' = 1.96 \int_{5.55}^{S} \frac{dS}{U_c} \qquad (37)$$

The time-temperature history just described is sketched below, up to the beginning of the zone of established flow where computer results are required.



Equations (26) through (35), and equation (37), were solved on a digital computer, using the temperature and density profile obtained from the oceanographic data for each site under consideration. The method by which the oceanographic data were reduced to the dimensionless form required by the governing equations, is presented in appendix A. Before giving results for each site, the effect of the ocean surface will be considered.

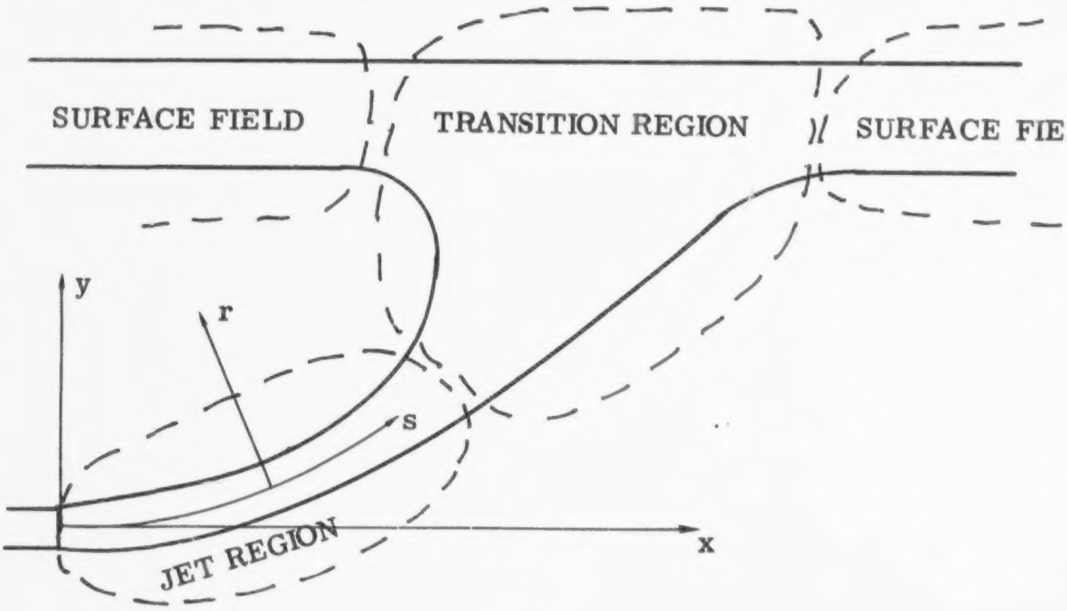
THE EFFECT OF THE OCEAN SURFACE

In an analysis of the thermal field resulting from the discharge of power plant cooling water, the effect of the surface of the receiving water must be considered. Eventually all the heat discharge is transferred through this surface to the atmosphere, the receiving water being simply a heat exchanger in the overall process.

The surface temperature may be influenced to a considerable extent by the plant designer who can vary the velocity or the direction, or both, of the cooling water discharge so as to get maximum dilution of the hot stream before it reaches the ocean surface. For example, a higher discharge velocity for a horizontal jet will project a longer stream into the receiving water, to result in a correspondingly greater dilution and thus lower surface temperatures. Of course, a proportionately larger amount of subsurface water is simultaneously affected by the warm stream.

From an ecological viewpoint the optimal thermal field for a specific site must be determined by a marine biologist. It is of interest to note that the thermal field for an ocean discharge can be regulated to a much greater degree than for river or coastal discharges.

The thermal and flow fields from a horizontal buoyant jet discharging in the vicinity of the ocean surface are sketched below.



The coordinate system is identical to that already described. As stated earlier, a literature search reveals a notable lack of analytical methods and very little experimental work on the combined problem of the buoyant jet and the surface field, although these problems are treated separately. The methods for analyzing a buoyant jet in an infinite fluid were presented previously. Results, based on these methods, are applicable in the jet region shown above where the surface effect is negligible. The point of departure from the jet to the transition region cannot be determined at this time.

The other extreme of the problem, which is the surface field, is treated in the literature, and one applicable analysis is that of Lawler et al (20), who consider an axisymmetric model with uniform conditions over a given constant field depth h. The authors assume that the heat transfer to the atmosphere is proportional to the temperature difference between the surface and the atmosphere. With these assumptions, the governing equation becomes Bessel's equation which has a closed form solution. Of course, the actual mechanism of heat exchange with the environment is very complex, and includes radiation, conduction, convection, and evaporation as discussed by Parker and Krenkel (25), and others. Because of the unknown coefficients associated with the actual modes of heat transfer, the author's assumption of one overall heat transfer coefficient is reasonable and widely accepted.

The governing differential equation for this model of the surface field is:

$$E \frac{d^2\theta}{dr^2} + \frac{1}{r} \left(E - \frac{Q_s}{2\pi h}\right) \frac{d\theta}{dr} - K\theta = 0$$

All notation is defined under Nomenclature. The above equation can be written in dimensionless form as:

$$\frac{d^2T_s^*}{d\zeta^2} + \frac{1}{\zeta}\left|1 - 2n\right| \frac{dT_s^*}{d\zeta} - T_s^* = 0 \qquad (38)$$

where

$$T_s^* = \frac{t_s - t_a}{t_m - t_a}$$

$$\zeta = \sqrt{\frac{K}{E}}\ r$$

$$n = \frac{Q_s}{4\pi h E}$$

The subscript m refers to the mean temperature at the center of the surface field, and the subscript s refers to the surface field. The boundary conditions for equation (38) are:

$$\zeta = 0 \qquad T_s^* = 1$$

$$\zeta \rightarrow \infty \qquad T_s^* \rightarrow 0$$

and the appropriate solution is:

$$T_s^* = \frac{2}{\Gamma(n)} \left|\frac{\zeta}{2}\right|^n K_n(\zeta) \tag{39}$$

where Γ is the gamma function and K_n is the modified Bessel function of the second kind and of order n. Equation (39) is valid for all values of $n > 0$; however, in his report, Lawler introduces another solution for n not equal to an integer. This solution does not meet the boundary condition as $\zeta \rightarrow \infty$ and is not valid. This does not change the results given in the report, because only values of n that are integers are considered, and for this case the authors use equation (39), which is valid. The solution of equation (39) is plotted in figure 11 for several values of n.

As pointed out by our consultant, Dr. D.R.F Harleman, in an unpublished communication, there is a more conservative method for predicting the surface field. In order to evaluate equation (39), it is necessary to choose values for the surface heat transfer coefficient K^*, the thermal diffusion coefficient E, and the depth of the surface field h. None of these values can be predicted with confidence, and results which depend on all three are certainly subject to question. Fortunately, a solution can be obtained which eliminates two of these parameters and yields conservatively high results for the surface temperature. If thermal diffusion is neglected, the

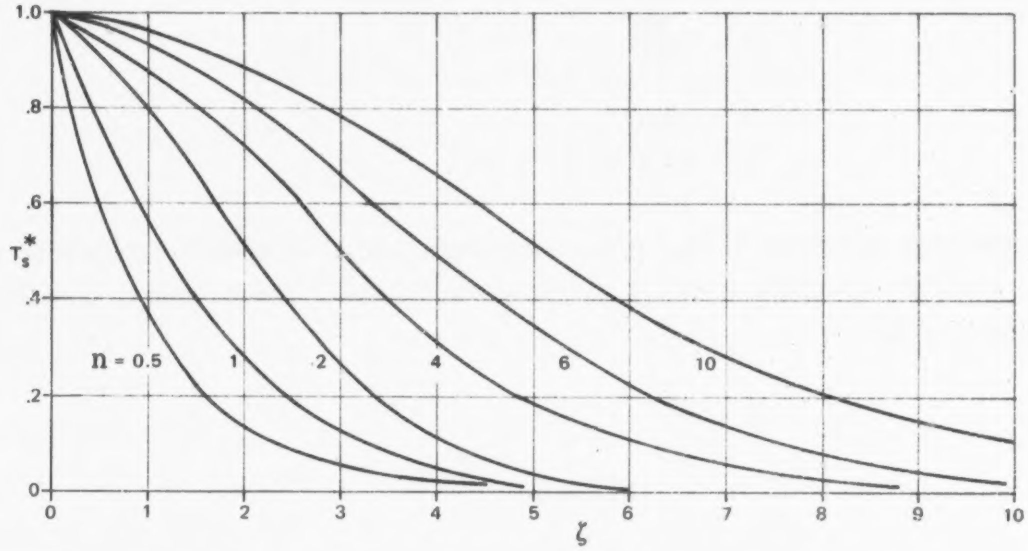


Figure 11. A Dimensionless Plot of Surface Field Temperature vs Radius for Various Values of n

governing equation becomes:

$$\frac{d\theta}{dr} + \frac{2\pi K^*}{Q_s \rho_s g C_p} r\theta = 0$$

The solution to this equation, in dimensionless form, is:

$$T_s^* = e^{-NR^2} \tag{40}$$

where

$$N = \frac{\pi K^* D^2}{Q_s \rho_s g C_p}$$

which is independent of the parameters E and h. Equation (40) is plotted in figure 12 for three values of N. For a typical surface heat transfer coefficient of 150 Btu/ft^2 day $^\circ$F, and a surface flow rate of $Q_s = 10\ Q_o$, the value of N is 1.4×10^{-6}. For this condition, the dimensionless surface temperature is down to less than 30 percent of the maximum value at a radial distance of 15000 ft. This is a higher temperature than would be obtained with Lawler's method, and is conservative in the sense of predicting a more severe surface field than would actually be obtained. For this reason, equation (40) is used to predict the temperature distribution in any surface field that might arise.

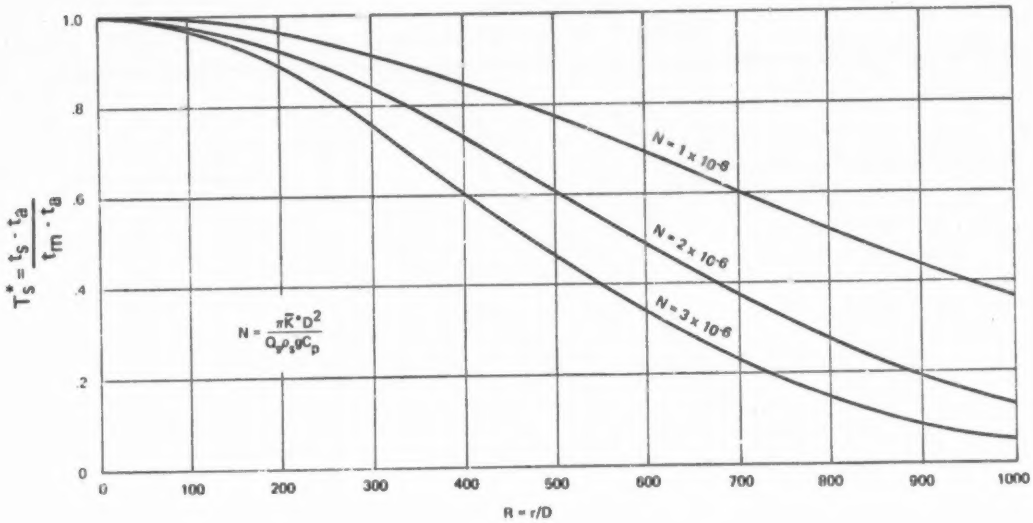
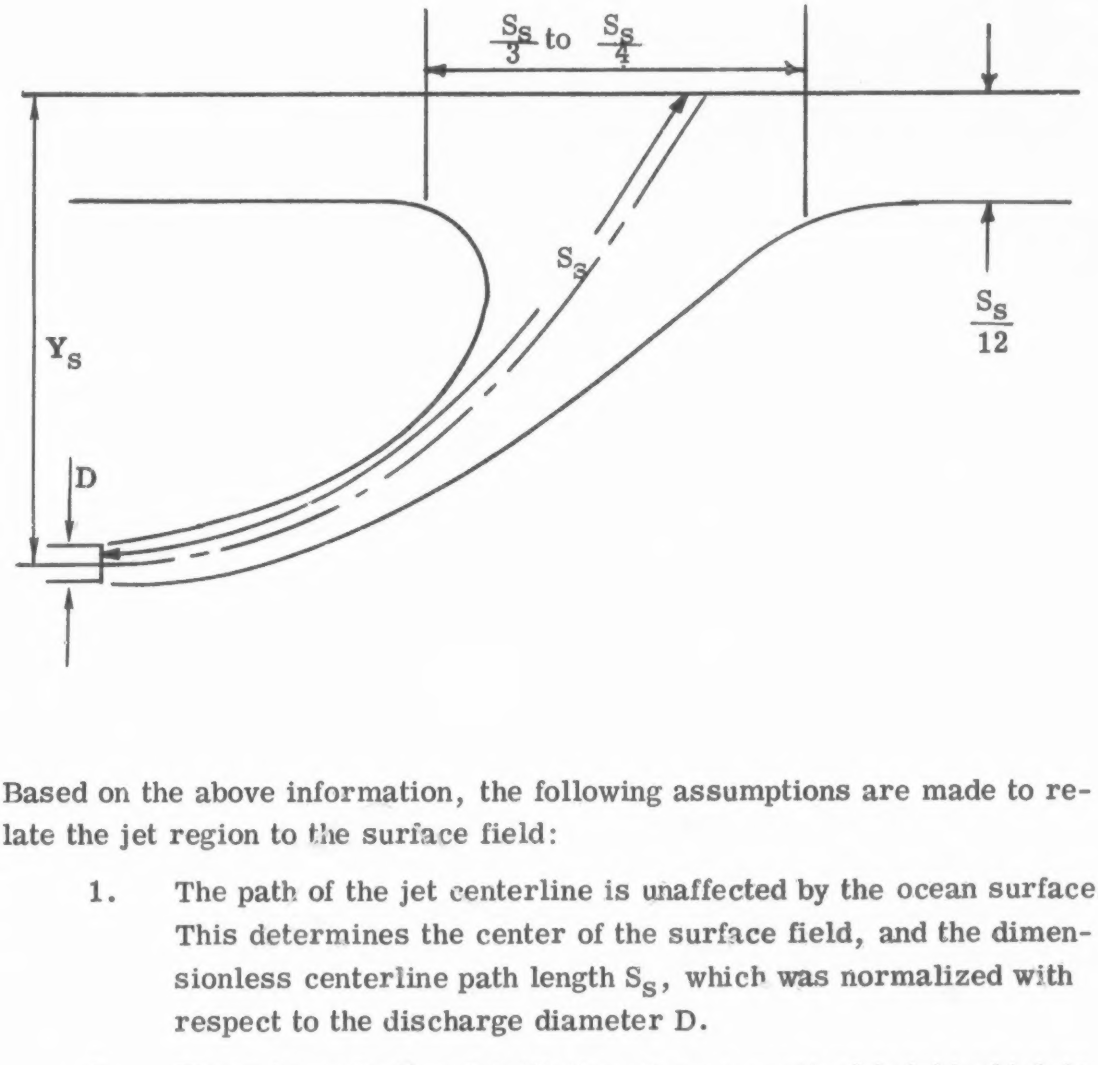


Figure 12. Surface Temperature vs Radial Distance with No Diffusion (Equation 40).

The problem to be considered now is that of relating the results for a buoyant jet in an infinite body of water, to the surface field which must be characterized in terms of a flow rate Q_s, and a maximum temperature t_m. Because analytical methods are not available, these values must be estimated from experimental results which are rather scarce.

Some experimental work was carried out by Frankel et al (13), who measured concentrations and, by implication, temperatures, in the region where the jet reaches the surface. The authors state that, in this region, there is a great deal of mixing within the jet but very little additional dilution by the ambient fluid, so that the concentrations are greater than would occur in the absence of the ocean surface. Also, the authors found that the maximum surface concentration is the same as the concentration at a certain point on the centerline of a buoyant jet in an infinite body of fluid. This point is at a vertical height which is 75 percent of the surface height. An estimate of the depth of the surface field, and the size of the transition region where the buoyant jet becomes a surface field, are presented by Hart (17), based on the experimental work of Rawn et al (28). The author gives the relative dimensions in a sketch as shown below.



Based on the above information, the following assumptions are made to relate the jet region to the surface field:

1. The path of the jet centerline is unaffected by the ocean surface. This determines the center of the surface field, and the dimensionless centerline path length S_s, which was normalized with respect to the discharge diameter D.
2. There is no further jet dilution above a vertical height which is 75 percent of the surface height, so that the mean temperature and flow rate at this point may be used to characterize the surface field.

3. The surface field is axisymmetric and uniformly mixed over the depth h, so that $t_s = t_s(r)$.

The last assumption neglects the jet momentum which would result in a thicker field in the direction in which the jet was pointed. The limiting case is when the jet centerline is normal to the surface, and the resulting field is truly axisymmetric.

Using the above assumptions, the temperature distribution in the surface field can be estimated by the following procedure:

1. Plot the thermal field and centerline path for a buoyant jet in an infinite fluid, using methods described previously.
2. Superimpose the ocean surface at Y_s.
3. Determine t_m and Q_s at $Y = 0.75\ Y_s$, from computer results obtained in step 1.
4. Compute N and determine the temperature distribution in the surface field from equation (40), or figure 12.

Results predicted with the method outlined above are approximate but conservative in nature. A thorough treatment of this problem would involve extensive analytical or experimental investigations beyond the scope of this study. It is shown later that the surface fields at each site are sufficiently low in temperature so that the exact description of the temperature distribution is not critical.

APPLICATION OF RESULTS TO SPECIFIC SITES

In this section, the analyses developed previously and in appendix B are applied to the four chosen sites. Of necessity, the results involve assumptions and engineering judgment, but are made on a conservative or worst case basis. For this reason, the predicted thermal field is larger, and higher in temperature, than would be expected at each site. The thermal field for the basic model of a single horizontal discharge, is determined for each site in both the summer and winter. These seasons represent extreme conditions, under which different thermal fields may be considered acceptable. The lines of constant temperature difference from the ambient are predicted for 1.5°F in the summer, and 4°F in the winter. The choice of these values is in keeping with the New York State standards (27), and the federal guidelines, which are discussed elsewhere. The mixing zone is defined as that region where the temperature difference exceeds the above standards.

In the oceanographic data presented in volume 2, maximum, minimum, and average values are given for density, temperature, and salinity at each site. Considering all three cases is not warranted, and the maximum value of temperature and the corresponding minimum value of density are used. This choice ensures that the maximum temperature is being considered, although it is possible that other combinations of temperature and density may result in larger mixing zones.

The boundary effect, due to the ocean surface, is estimated by using the procedure outlined on page 81. In this procedure, the flow rate and maximum temperature of the surface field are taken to be the flow rate and mean temperature of the jet at a certain vertical height from the point of discharge. This height is 75 percent of the vertical distance to the surface. This is taken as the transition point between the jet and the surface field. If the mixing zone, as predicted for a buoyant jet in an infinite body of fluid, lies wholly below this transition point, then the resulting surface field is sufficiently low in temperature to meet the standards, and the temperature distribution is not predicted.

The combination of the results for a current and stratification presents a more difficult problem. The analysis described in appendix B considers a buoyant jet in an infinite, homogeneous fluid, with a current of arbitrary direction. However, the results depend on two constants which must be determined experimentally; at present, they are available only for a vertical jet in a cross flow (11). As was done in appendix B, this difficulty can be overcome, for some cases, by choosing values for the constants that yield results for the worst case. These constants were used to obtain the results shown by figure 13, which predicts the deflection of the jet centerline for various current velocities in a homogeneous fluid. The amount of deflection is not highly dependent on the Froude number, which varies from site to site, with an average value of about six. On this basis, the results shown by figure 13 are applied to all sites. Only the cases of a following and an opposing current have been considered, because these represent the worst conditions with respect to extending the size of the thermal field, and recirculating condenser discharge.

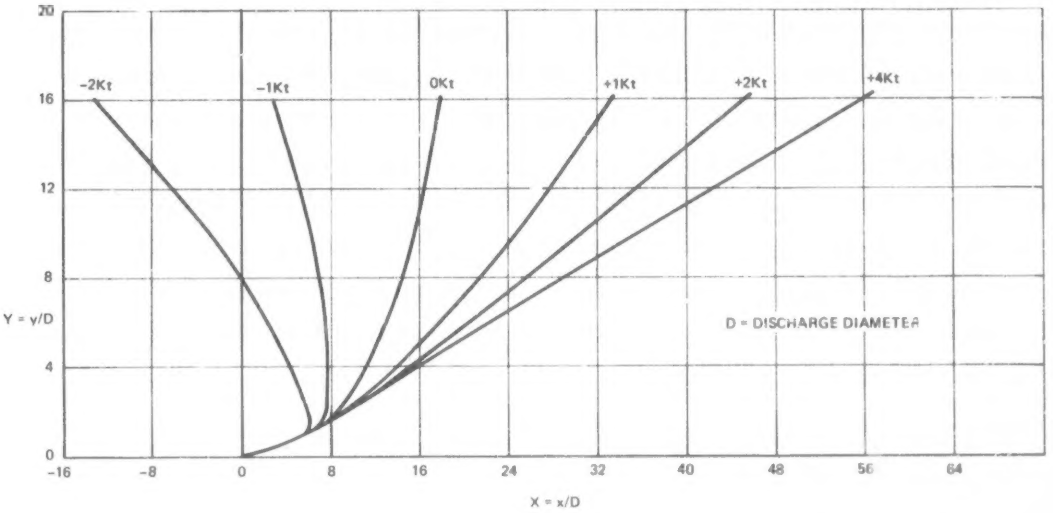


Figure 13. Centerline Paths of a Horizontal Buoyant Jet Discharging into an Infinite Body of Homogeneous Fluid with Various Following (+) and Opposing (-) Current Conditions. F = 6.0

In a stratified fluid, the effect of a current on the jet is approximated by a single, horizontal translation of the jet centerline by an amount equal to that given by figure 13. In other words, a point on the jet centerline in a stratified fluid, at a vertical distance y, is shifted horizontally by the same amount as a jet in a homogeneous fluid with a current at the same vertical distance. It is assumed that the isotherms are translated in the same manner.

The only justification for this procedure is, that the results of figure 13 are conservative to such a degree that the application of the method outlined above also yields conservative results.

Using the methods just discussed, and the ambient temperature and density distribution given in appendix B, the thermal fields for the chosen sites are predicted below.

Waters off Southeastern Florida

In the case of the waters off Southeastern Florida, the thermal field with no current is predicted and the results shown by figure 14 for the summer, and figure 15 for the winter. Additional jet centerline paths are shown for a 2-knot current, both following and opposing, and for a 4-knot following current. The paths were determined by the method described previously. The 2-knot and 4-knot current magnitudes are the highest values given in the oceanographic data for the Southeastern Florida site. The 4-knot case is due to occasional excursions of the Gulf Stream into the site, resulting in a high velocity toward the north. It is assumed that the condenser discharges to the north so that the 4-knot opposing current need not be considered. The 2-knot case represents a maximum condition under normal circumstances. The velocity can be either northerly or southerly, so both a following and an opposing current must be considered.

From figure 14 it can be seen that, in the summer, the jet only rises about 130 ft. Actually, at 80 ft from the bottom, the jet centerline temperature is the same as the ambient ocean temperature, but the vertical momentum carries the jet another 50 ft. The ocean surface, to a depth of 150 ft, is unaffected thermally by the condenser discharge. The gross effect is an insignificant thickening of the epilimnion caused by the addition of the heated water. If the jet were discharging into a confined body of water, such as a lake, the thickened epilimnion would alter the cycle by which the thermal stratification changes during the year. The same phenomenon occurs in the sea but to a minute degree. Tidal currents and coastal drift ensure that, for all practical

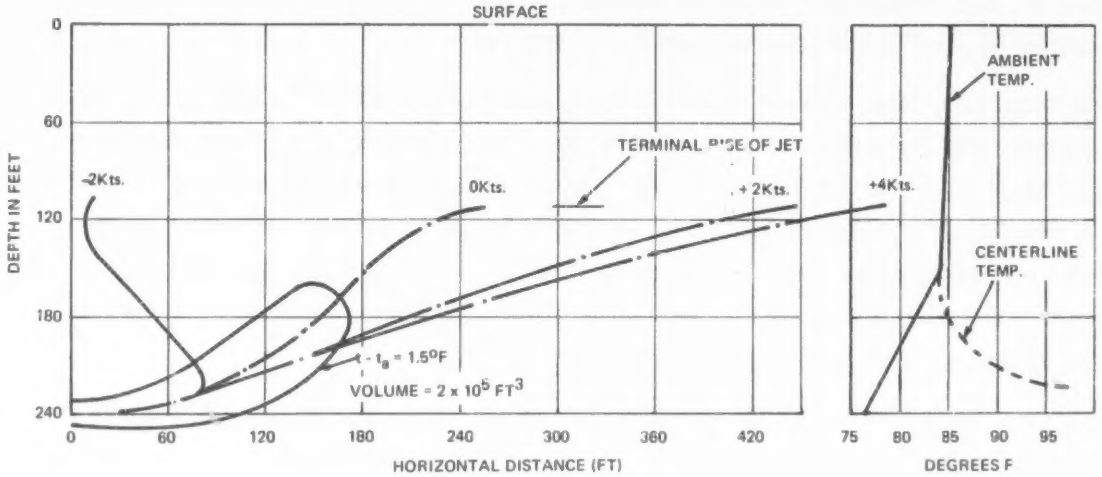


Figure 14. Thermal Field for the Site Off Southeastern Florida in the Summer under Extreme Following (+) and Opposing (-) Currents. F = 5.35

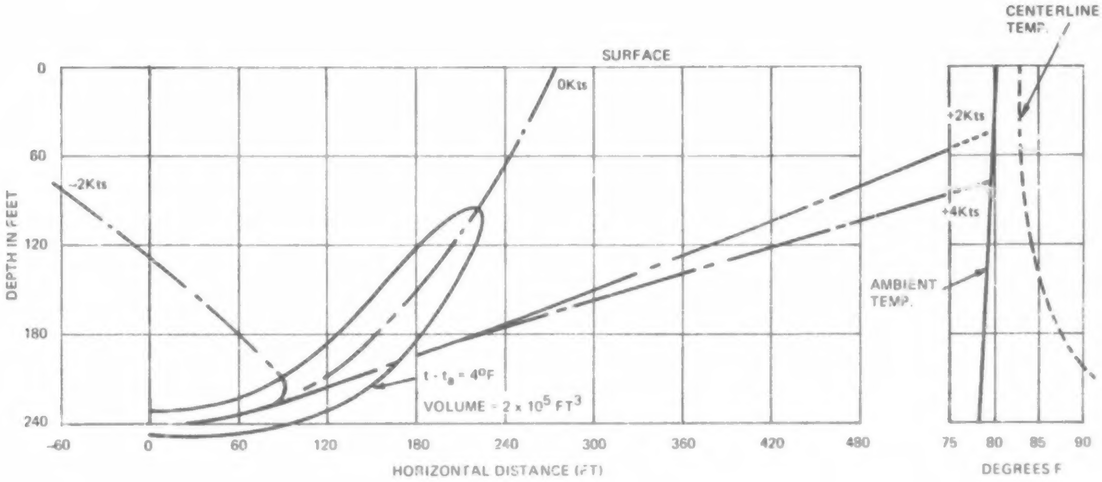


Figure 15. Thermal Field for the Site Off Southeastern Florida in the Winter under Extreme Following (+) and Opposing (-) Currents. F = 5.35

purposes, the discharge water is thermally indistinguishable from the ambient water beyond the region shown in figure 14.

In the summer, the volume of the mixing zone is 2×10^5 ft^3, which can be compared with the maximum mixing zone of the planned Shoreham Nuclear Power Station. The latter zone will probably have an average depth of 15 ft* and a maximum radius of 300 ft, giving a volume of 42.4×10^5 ft^3. This coastal power station, which will be one of the first to meet the stringent New York State requirements, will affect a body of water about 20 times larger than would a deep water ocean installation.

In winter, the jet reaches the surface as shown in figure 15, but at a depth of 60 ft, which is the transition point, the centerline temperature rise is less than 3°F. Equation (36) gives a maximum surface temperature rise of $t_m - t_a = 0.573 \times 3 = 1.72^{\circ}F$. This value easily meets the winter standards, and it can be seen that the mixing zone ends below a depth of 90 ft, so that the ocean surface is not affected by the discharge water. The volume of the mixing zone is the same as in the summer.

A further item of interest is the temperature-time history of the cooling water, which is the environment of the organisms drawn through the condenser. Considering the centerline (the hottest portion of the jet), the lower curve of figure 16 gives the duration of the maximum temperature to which the plankton could be exposed. Also shown by figure 16 is the jet flow rate as a function of time. It can be seen that the flow rate of the jet increases by entrainment to about nine times the condenser flow rate before a surface field is formed in the winter. The entrainment occurs at the periphery of the jet where the temperatures are the lowest, so that most of the entrained water never reaches the maximum centerline temperature given by figure 16.

Gulf of Maine

The mixing zone and jet centerline paths for maximum current conditions in the selected Gulf of Maine area, are shown by figure 17 for the summer and for the winter. The 1-knot current is the highest value given in the oceanographic data for the Gulf of Maine site. The ambient temperature distribution

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*Taken from an abstract of a Long Island Lighting Co report entitled Environmental Statement, Shoreham Nuclear Power Station, Plant Unit 1; Docket 50-322, June 1, 1970.

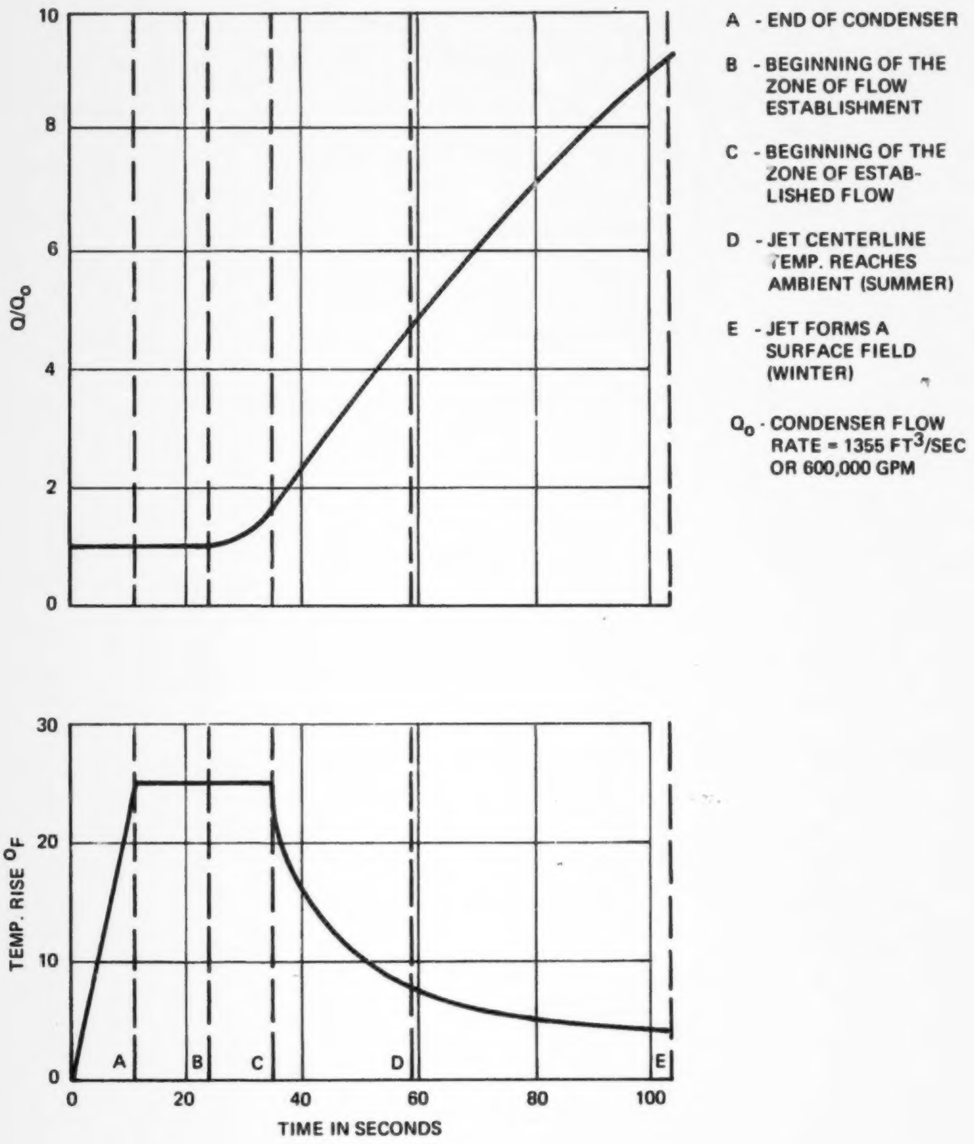
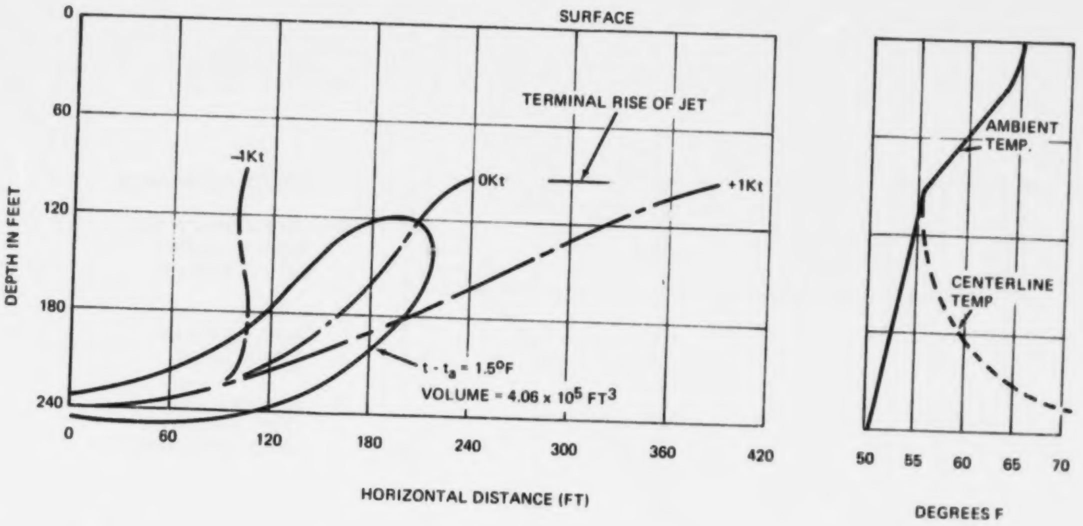
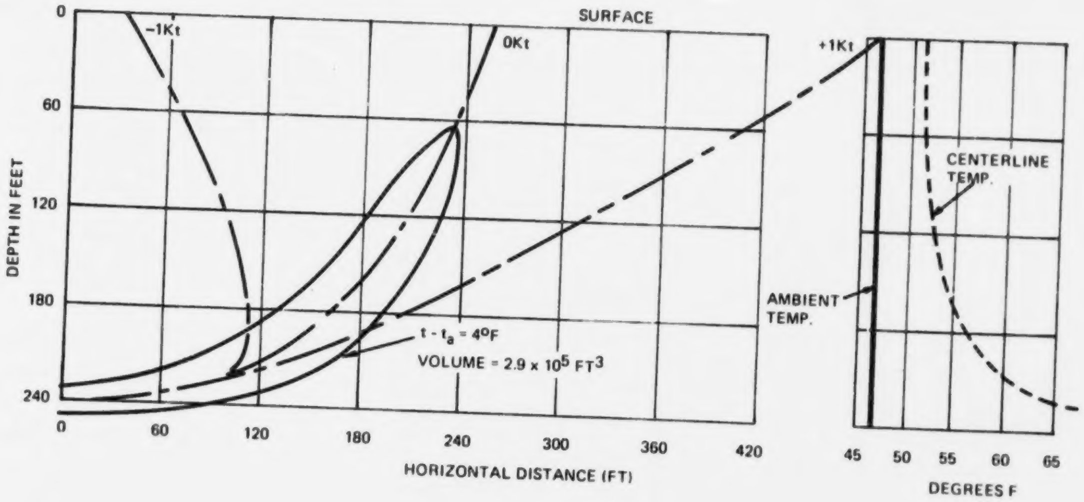


Figure 16. Flow Rate Ratio and Maximum Temp Rise vs Time for Flow in the Condenser and Jet for the Site off Southeastern Florida in the Summer and Winter with Zero Current.



In the Summer. F = 6.18



In the Winter. F = 6.48

Figure 17. Thermal Field for the Gulf of Maine Site under Extreme Following (+) and Opposing (-) Currents

is characterized by a sharp, but relatively shallow, thermocline in the summer, and an isothermal profile in the winter. In the summer, the jet centerline temperature is reduced to that of the ambient at a depth of about 100 ft, and the jet does not rise appreciably beyond this point. The ocean surface is completely unaffected at depths less than 100 ft. The 1.5°F mixing zone terminates at a depth of about 120 ft and has a volume of 4.06×10^5 ft^3.

In the winter, the mixing zone terminates at a depth of about 60 ft, which is the transition point between a buoyant jet and a surface field for a depth of 240 ft. Using equation (36), the maximum temperature of the surface field is found to be:

$$t_m - t_a = 0.573 \times 4 = 2.3^\circ F$$

This value is well within the winter standards, and it can be seen that the ocean surface is relatively unaffected to a depth of 60 ft. The volume of the mixing zone is 2.9×10^5 ft^3 in the winter.

The maximum temperature and flow rate versus time of the cooling water and the jet are shown by figure 18. These results are similar to those of the Southeastern Florida waters except in the summer, when the jet reaches the ambient temperature much more quickly in the Florida area.

The New York Bight

The mixing zone and jet centerline temperatures for the selected region of the New York Bight, are plotted in figure 19 for the summer, and figure 20 for the winter. The maximum current expected at this site is 0.5 knot, so that that the centerline paths given in the figures for a 1-knot current are clearly worst cases. The ambient temperature distribution is similar to that of the Gulf of Maine site except that the stratification in the summer is more severe in the bight. The mixing zone volumes are 3.95×10^5 ft^3 in the summer, and 2.8×10^5 ft^3 in the winter. The surface field that forms in the winter is practically identical to that at the Maine site, and has a maximum temperature rise of 2.3°F. In the summer, the jet centerline temperature reaches that of ambience about 100 ft from the bottom, so that the sea water is unaffected thermally to a depth of about 140 ft.

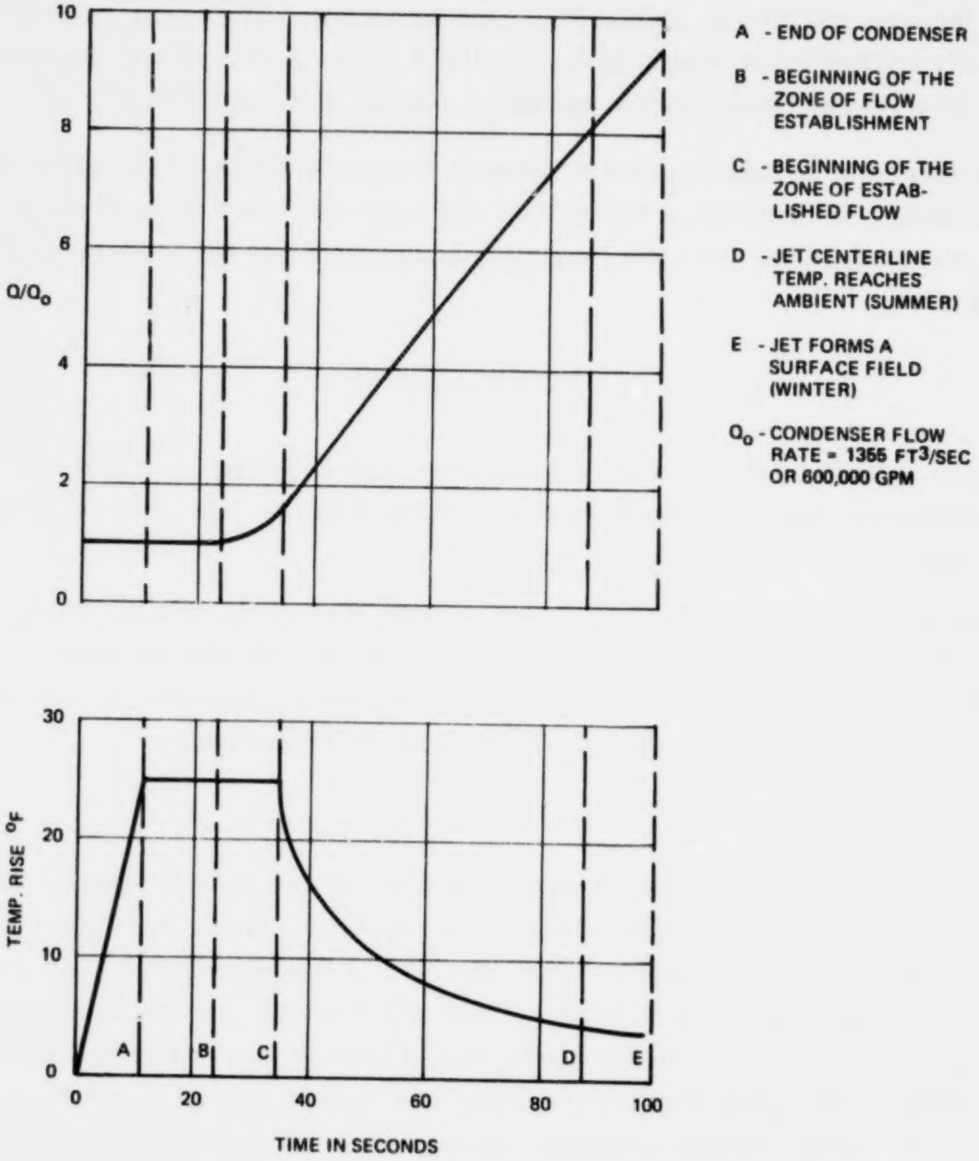


Figure 18. Flow Rate Ratio and Maximum Temp Rise vs Time for Flow in the Condenser and Jet at the Gulf of Maine Site in the Summer and Winter with Zero Current

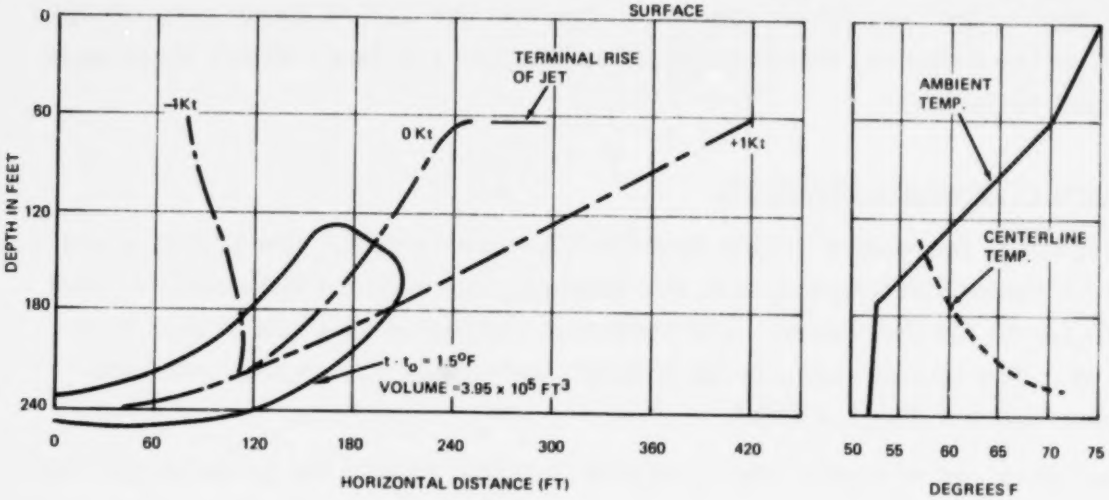


Figure 19. Thermal Field for the New York Bight Site in the Summer under Extreme Following (+) and Opposing (-) Currents. F = 6.12

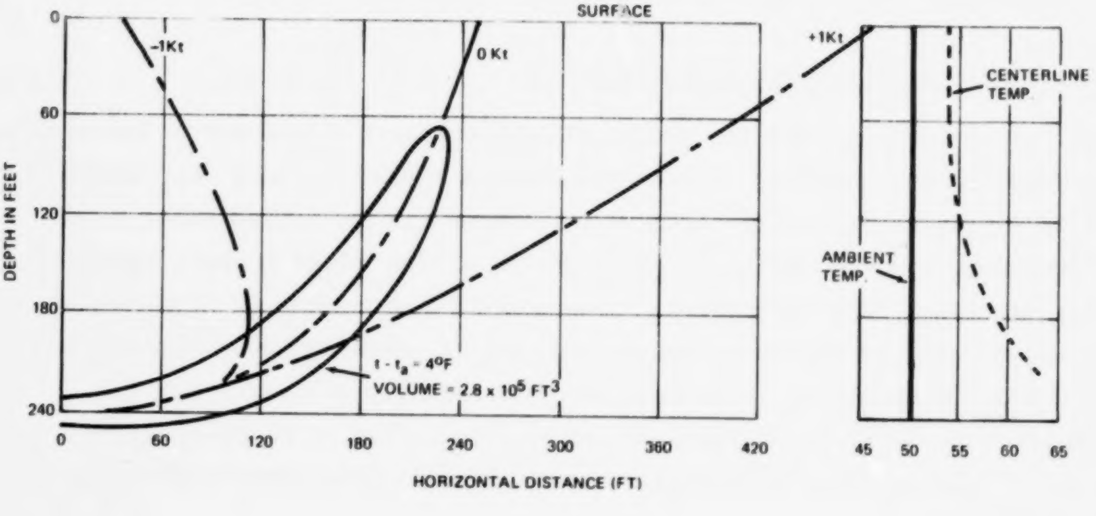


Figure 20. Thermal Field for the New York Bight Site in the Winter under Extreme Following (+) and Opposing (-) Currents. F = 6.17

The flow rate and jet centerline temperature versus time are shown by figure 21. Again, the results are similar to those in the Gulf of Maine area except that, in the summer, the centerline temperature reaches ambient level more quickly in the bight.

Waters off Southern California

In regard to the waters off the southern Californian coast, the mixing zones and jet centerline temperatures are shown in figure 22 for the summer, and in figure 23 for the winter. The maximum current at this site is less than 0.7 kt. The mixing zones in the summer and winter are similar, and terminate below a depth of 120 ft.

In summer, as in winter, the predicted terminal rise of the jet is beyond the transition point where the jet forms a surface field. In both cases, the centerline temperature reaches ambient level before the transition point, so that the surface field is formed because of momentum and is at the ambient temperature. The ocean surface is unaffected thermally to a depth of 100 ft all year. The mixing zone volume is 3.5×10^5 ft^3 in the summer, and 1.75×10^5 ft^3 in the winter. The flow rate and centerline temperature versus time are plotted in figure 24, and are similar to those at the other sites.

CONDENSER DISCHARGE RECIRCULATION

In any power plant installation, heated discharge water should not be recirculated through the condenser. This possibility is minimized in a deep water plant where the condenser intake is at the bottom and the heated water rises. For the entrainment of discharge water to occur, the intake suction must overcome the discharge buoyancy. Flow under these conditions is governed by the dynamics of a nonhomogeneous fluid as discussed by several authors (5, 15, 37). An estimate of the inlet velocity required to recirculate the discharge water can be obtained from an equation given by D. R. F. Harleman (15). The equation and geometry for the two-layered axisymmetric model are given below.

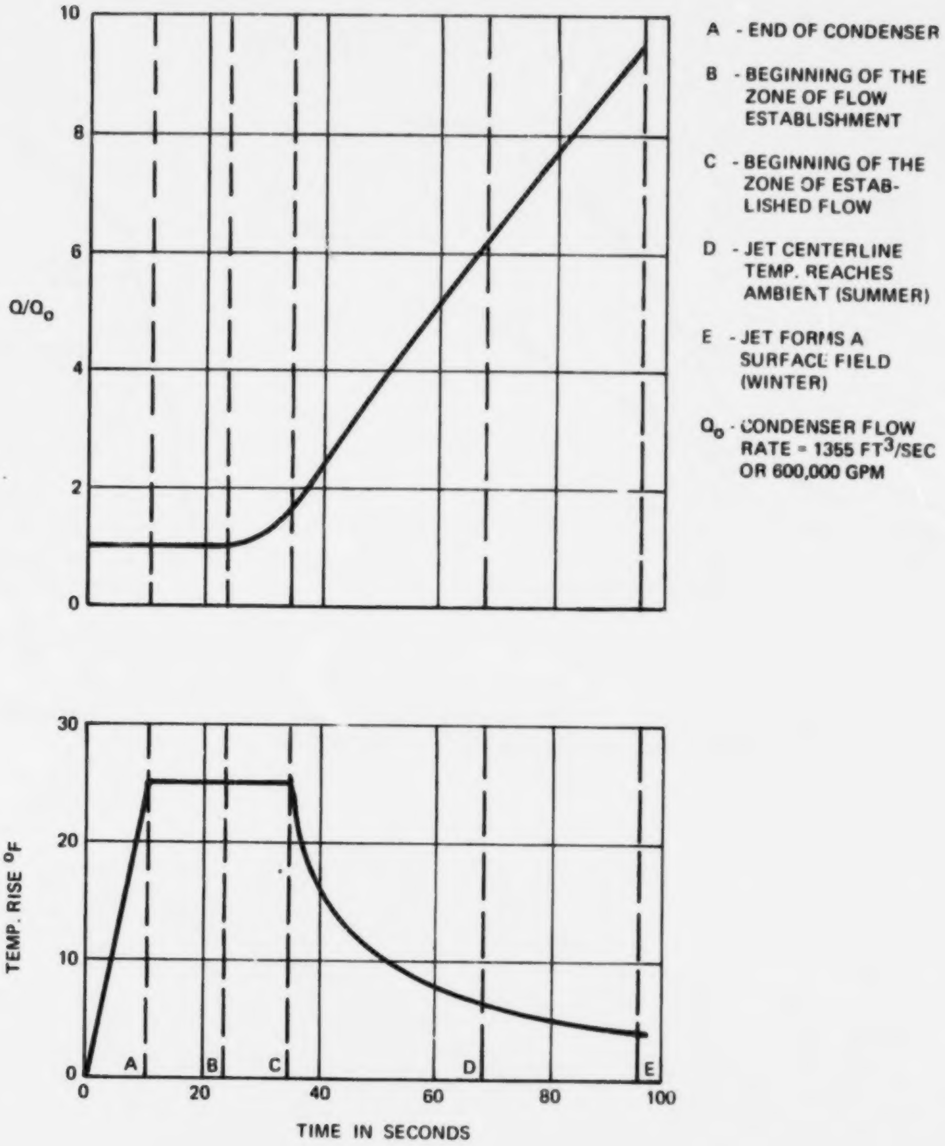


Figure 21. Flow Rate Ratio and Maximum Temp Rise vs Time for Flow in the Condenser and Jet at the New York Bight Site in the Summer and Winter with Zero Current

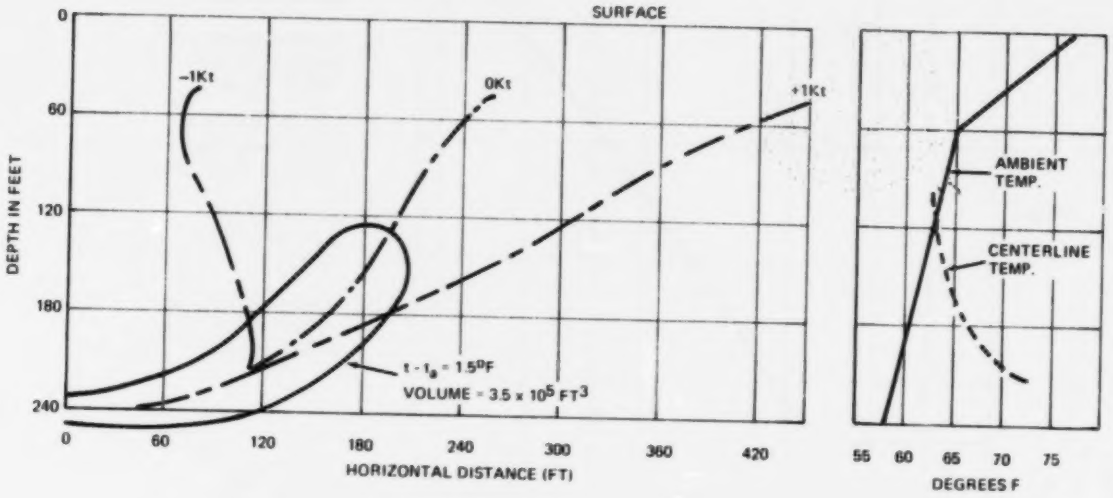


Figure 22. Thermal Field for the Southern California Site in the Summer under Extreme Following (+) and Opposing (-) Currents. F = 5.74

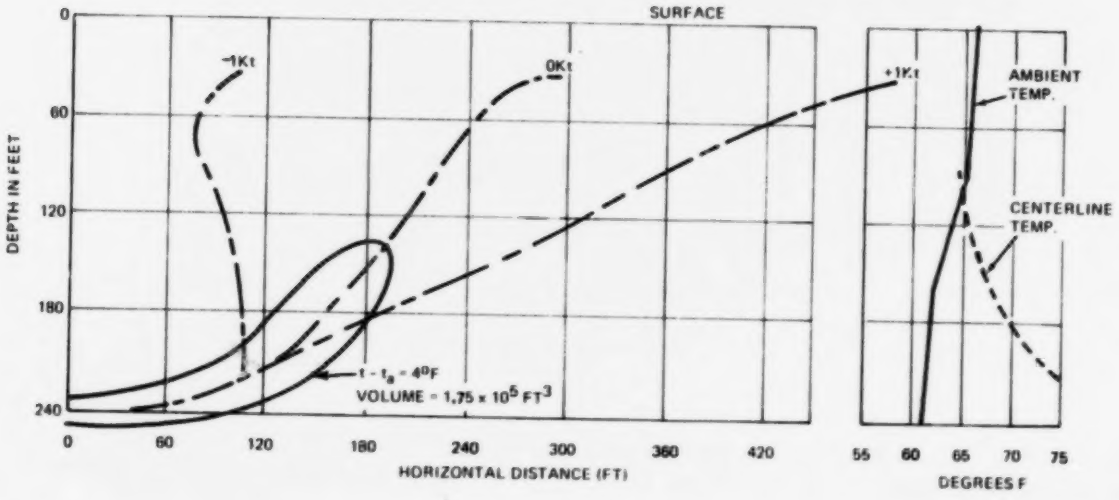


Figure 23. Thermal Field for the Southern California Site in the Winter under Extreme Following (+) and Opposing (-) Currents. F = 5.62

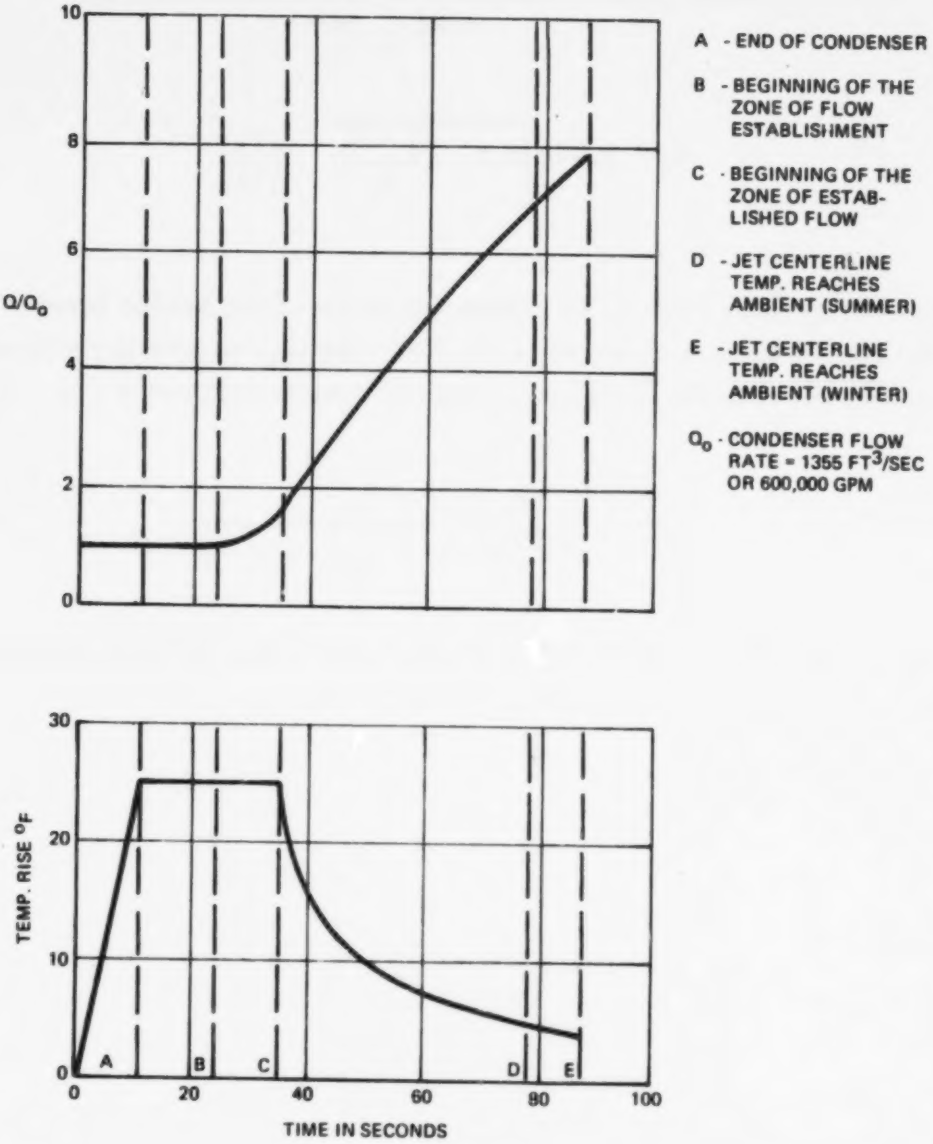
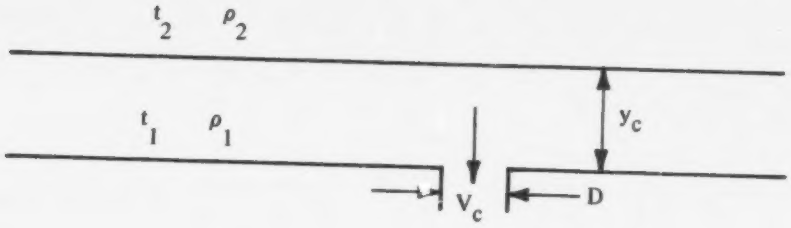


Figure 24. Flow Rate Ratio and Maximum Temp Rise vs Time for Flow in the Condenser and Jet at the Southern California Site in the Summer and Winter with Zero Current



$$V_c = 2.05\sqrt{y_c g \; \frac{\rho_1 - \rho_2}{\rho_1}} \; \left(\frac{y_c}{D}\right)^2 \qquad (41)$$

Any velocity greater than V_c will cause ingestion of the heated layer. Equation (41) can be written in terms of the flow rate Q_o, to give the following relationship between the distance y_c and the density difference $(\rho_1 - \rho_2)/\rho_1$:

$$y_c^{\,5} = \left[\frac{4Q_o}{2.05\pi}\right] \frac{1}{g\left\{(\rho_1 - \rho_2)/\rho_1\right\}} \qquad (42)$$

With Q_o = 1355 ft^3/sec, and using a linear relationship between temperature and density, equation (42) is plotted as figure 25.

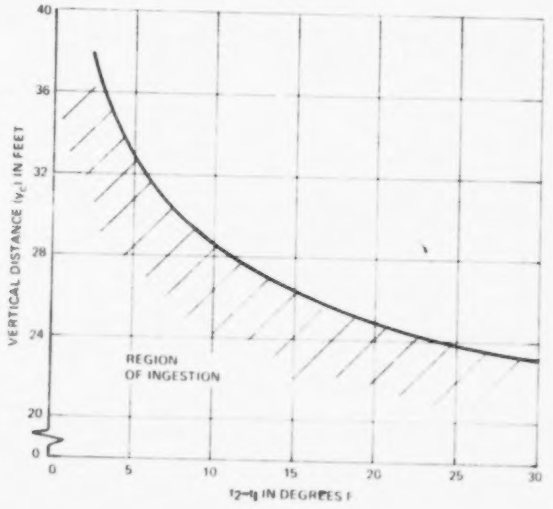


Figure 25. A Plot of Eq (42) Showing the Minimum Vertical Separation to Prevent Ingestion of a Heated Layer at Temp t_2 through Inlet at t_1 (see sketch above), with a Flow Rate of 1355 ft^3/sec

The results show that recirculation can be avoided if any part of the jet that has a temperature in excess of the ambient, remains at least 50 ft above the inlet. Although these results are based on a rough model of the actual geometry, they do indicate the approximate extent of the required separation.

The worst case arises when the current carries the condenser discharge in the direction of the inlet. This is why the centerline displacement for an opposing current is plotted for each site, although the values chosen are considerably higher than the bottom current which is usually much less than 2 knots. The results, and the general shape of the isotherms in the jet, provide some insight as to the thermal field in the vicinity of the inlet. There are also design options such as arranging the discharge to flow in the direction of the prevailing current, and positioning it above the inlet.

In summary, recirculation can be avoided by controlling the thermal field to the extent possible with a deep water discharge, although model tests may be required for a final design.

COMMENTARY

All thermal fields presented for the specific sites illustrate the advantages of a deep water discharge. Although this may appear to be an obvious contention, the results given herein provide support for it.

The mixing zones are considerably smaller than those of a coastal installation, and are confined to the lower regions of the ocean sites. The biological aspects of this are discussed elsewhere. The thermal fields are predicted for the basic model of a single-point discharge with no attempt at optimization. In every case, the mixing zone ends before either a surface or subsurface field is established. This is an important finding because, in a surface field, the temperature decreases very slowly with distance, and it would be difficult to meet the thermal standards if the maximum temperature rise exceeded the allowable values of 1.5°F in the summer, and 4°F in the winter. Furthermore, such a field might affect shoal areas by drifting or upwelling. This situation does not develop in any of the cases treated here, because there is enough dilution of the jet so that the maximum temperature rise at the surface is safely below the thermal standards.

It is emphasized that these results are obtained using rather arbitrarily chosen values for the condenser operating condition and discharge design. For any given deep water site, these variables could be manipulated to give an improved thermal field. Similarly, any possibility of recirculating the condenser cooling water can be precluded.

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NOMENCLATURE

English Symbols

$B = b/D$	dimensionless local characteristic radius
$b =$	local characteristic radius (ft)
$c_p =$	specific heat (Btu/lb ^{o}F)
$D =$	discharge jet diameter (ft)
$E =$	thermal diffusion coefficient (ft^2/sec)
$F = u_o \Big/ \sqrt{g \dfrac{(\rho_a - \rho_o) D}{\rho_o}}$	densimetric Froude number
$g =$	gravitational acceleration (ft/sec^2)
$H = h/D$	dimensionless surface field depth
$h =$	surface field depth (ft)
$K^* =$	surface heat transfer coefficient (Btu/ft^2 sec ^{o}F)
$K = \dfrac{K^*}{\rho g c_p h}$	temperature dissipation coefficient (1/sec)
$k =$	dimensionless local variable defined in equation (3)
$N = \dfrac{\pi K^* D^2}{Q_s \rho_s g\, c_p}$	dimensionless parameter
$n = \dfrac{Q_s}{4\pi h E}$	dimensionless parameter
$P = \dfrac{\rho_{oa} - \rho}{\rho_{oa} - \rho_o}$	dimensionless density ratio
$Q =$	flow rate (ft^3/sec)
$R = r/D$	dimensionless radial distance from the jet centerline
$r =$	radial distance from jet centerline (ft)
$S = s/D$	dimensionless distance along the jet centerline
$s =$	distance along jet centerline (ft)

$T^*_s = \dfrac{t_s - t_a}{t_m - t_a}$ dimensionless surface temperature

$T = \dfrac{t - t_{oa}}{t_o - t_{oa}}$ dimensionless temperature ratio

$t =$ temperature (^{o}F)
$U = u/u_o$ dimensionless velocity ratio
$u =$ velocity (ft/sec)
$V = v/D^3$ dimensionless volume
$v =$ volume (ft^3)
$X = x/D$ dimensionless horizontal coordinate
$x =$ horizontal coordinate (ft)
$Y = y/D$ dimensionless vertical coordinate
$y =$ vertical coordinate (ft)

Greek Symbols

$\alpha =$ dimensionless entrainment coefficient
$\beta =$ angle of inclination of the jet centerline (radians)
$\eta =$ time (sec)
$\gamma =$ dimensionless constant temperature difference
$\lambda =$ dimensionless turbulent Schmidt number
$\mu =$ dimensionless local variable defined in equation (4)
$\rho =$ water density ($lb\text{-}sec^2/ft^4$)
$\theta = t_s - t_a$ surface temperature difference (^{o}F)
$\zeta = \sqrt{\frac{K}{E}}\, r$ dimensionless surface radius

Subscripts

a = condition in the ambient fluid
c = condition at the jet centerline
e = end of zone of flow establishment
γ = condition on a surface of constant temperature difference
m = mean condition
o = condition in the jet at the point of discharge
oa = condition in the ambient fluid at the discharge depth
s = surface

Note: barred quantities are functions of both R and S

Section 6

POTENTIAL EFFECTS OF THERMAL DISCHARGES ON MARINE POPULATIONS

Despite a large literature concerning the effects of temperature on marine organisms, the available information generally cannot be used to predict quantitatively the ecological effects of thermal discharges. The reasons are:

1. The various responses to anticipated temperature changes of organisms important to offshore sites have not been studied.
2. The coefficients relating responses to temperature changes have not been derived.
3. The distribution of various organisms in space and time, and their interdependence, have not been defined in the detail required.
4. The physiochemical environment at sites of thermal discharges is not known in sufficient detail.

The physiological or behavioral response of organisms to thermal discharge can range from the beneficial to the lethal. The response depends on the change in temperature, the rate of change, the period of exposure to the new temperature, the physiological state of the organism, and the environment of the organism when subjected to the thermal change. Similar considerations apply to any other environmental influence; some of these are discussed briefly below.

PLANT OR ANIMAL CONSIDERATIONS

Plants and animals evolve through a succession of stages, generally distinguishable morphologically. Each stage may respond to or be affected by an environmental influence differently. As a consequence, when plants or animals are studied to determine tolerances, biological characteristics such as life stage, age, size, weight, physiological state, adaptive state, prior environmental history, and genetic constitution, must be defined as carefully as possible, if the experimentally determined tolerances are to be generally useful. Definition of all these factors is technically difficult and compromises are generally made.

The survival of an organism depends on:

1. Maintenance of subcellular organization as determined genetically.
2. Availability of an energy supply and environment suitable for growth and sustenance.
3. The capacity to reproduce at a satisfactory rate.

Environmental influences on an organism are often termed normal, optimal, sublethal, or lethal. Normal refers to the range of environmental conditions that an organism generally experiences in its habitat, and with which it can successfully cope for survival. Optimal refers to environmental conditions in which energy expended by the organism for survival is minimal. An organism barely capable of coping with an influence, but capable of adjusting to it or regaining its former viability if the influence is removed in time, is said to be stressed or subjected to a sublethal influence. When the organism's ability to adjust is exceeded, and the effect on it becomes irreversible because of subcellular disorganization, the environmental influence is termed lethal. A highly idealized curve giving rate of response to environmental influences is shown in figure 26 to illustrate these relationships. Responses of organisms to environmental influences are largely exponential functions.

Biologists use many different measurements of life processes in assessing the effects of the environment. These can be conveniently grouped into four categories: physiological, morphological, behavioral, and populational. Some examples of these measurements are:

Physiological -- photosynthetic rate, respiratory rate, feeding rate, digestion rate, heart beat rate, fecundity, susceptibility to parasites and disease, and enzyme activity.

Morphological -- mean size, ontogenetic development, and chromosome aberrations.

Behavioral -- swimming speed, success in food capture, migration, and spatial distribution.

Populational -- growth rate and reproduction or mortality rate for populations of single, specific organisms; diversity indices for populations of mixed organisms.

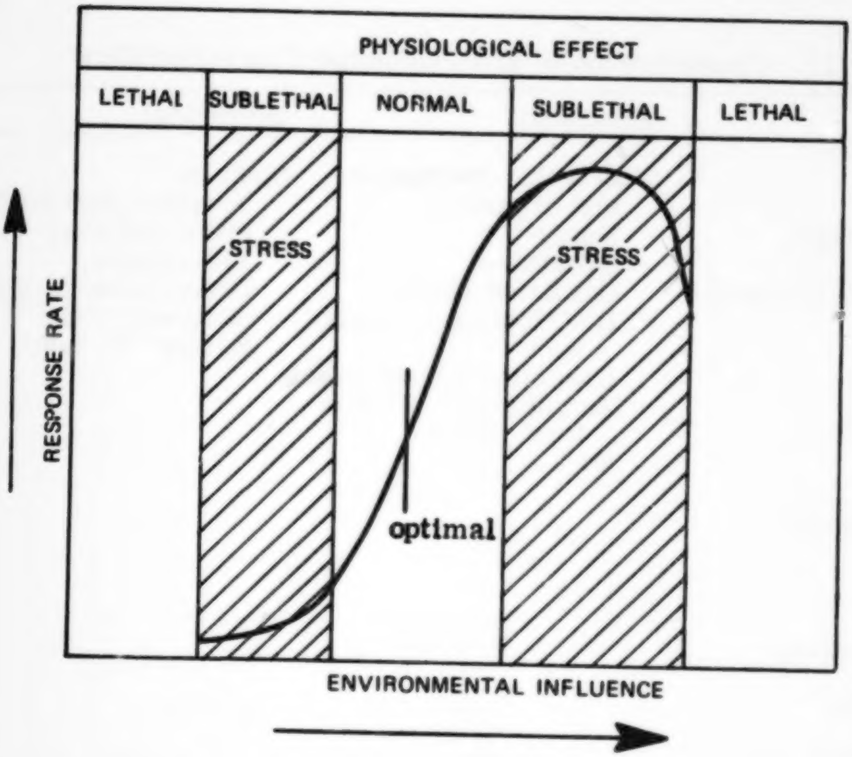

Figure 26. Idealized Rate of Response to Environmental Influence

Physiological, morphological, or behavioral measurements are used primarily in defining the optimal or sublethal environmental influences, while measurements of populational characteristics are used for establishing lethal as well as optimal or sublethal effects.

CONSIDERATIONS INVOLVING ENVIRONMENTAL CHARACTERISTICS

Environmental characteristics used in describing the environment under various circumstances are often grouped under physical, chemical, geological, and biological headings as shown by table 10. Some features that are biologically important are given under each heading.

It is important to note the many characteristics that collectively define environment, the many interactions possible between organisms and their environment, and the interdependence of many physical or chemical characteristics even in the absence of life. For example, if temperature is increased, water viscosity and the solubility of dissolved gases will diminish. In evaluating thermal effects,

Table 10. Classification of Environmental Characteristics

Physical	Chemical	Biological
Temperature Absolute Rate of change Duration Distribution in space/time Salinity As above Density Pressure Absolute Rate of Change Light Intensity Quality Photoperiodicity Turbidity Distribution Dissolved gases (O_2, CO_2, etc) Quantity Distribution in space/time Water circulation Direction Rate Period Boundary conditions Estuary, ocean Intertidal, benthic, pelagic, etc.	Nutrients: inorganic and organic Kinds Quantities Oxidation states Distribution in space/time Essential-nonessential Stimulatory -- inhibitory-lethal pH	Species Numbers and kinds Mass and size Life stages Distribution in space/time Metabolic role Ecological role

Geological
Substrate classification
Mineral composition
Quantity of organic matter
Topography

therefore, indirect as well as direct temperature effects on living organisms must be considered. The indirect effects in some cases may be more important than the effects of the temperature increase itself.

ECOLOGICAL CONSIDERATIONS

Considering the thousands of species of organisms involved and the complications mentioned above, it must be apparent that ecology -- the study of organisms interacting with their environment -- is a very complex subject.

Consequently, certain simplifications are commonly employed. For example, plants and animals associated with one another are classified into communities based on the dominant species, or grouped into trophic levels. Thus, phytoplankton as a group are used as a measure of primary productivity, and ecological stability is evaluated in terms of diversity indices. The point is that ecology has not progressed far enough to accurately predict power plant influences with any considerable degree of confidence. Empirical evaluations must be made, based on "before and after" field observations, complemented by a study of simpler life systems in the laboratory.

Biological field studies often suffer from the disadvantage of spectacular natural variation, which makes the detection of small ecological changes difficult statistically. Elucidating the factors responsible for any real biological change is also difficult, because multiple factors are simultaneously affecting measurements. Since life affects the physiochemical world and vice versa, living organisms cannot be studied apart from their environment, and relatively subtle changes in environmental characteristics can have profound effects on living things. Furthermore, the reproduction of real environmental conditions in the laboratory is extremely difficult in multifactorial experiments. While some of the studies needed to improve on ecological prediction are underway, much remains to be done, particularly with regard to the tropical environment.

THERMAL DISCHARGE STANDARDS AS GUIDELINES

The increasing need for electrical power, and the projected increase in thermal discharges, has prompted the Environmental Protection Agency to adopt standards for thermal discharges to minimize harmful ecological effects. Based on a careful review of available information and personal experience, a panel of experts constituted as the Subcommittee for Fish, Other Aquatic Life and Wildlife of the National Technical Advisory Committee, reached a "best-judgment" consensus that the following thermal standards should apply to estuarine or coastal waters exclusive of the zone of passage:

> "Monthly means of the maximum daily temperatures recorded at the site in question and before the addition of any heat of artificial origin should not be raised by more than 4°F during the fall, winter, and spring (September through May), or by more than 1.5°F during the summer (June through August). North of Long Island and in the waters of the Pacific Northwest (north of California), summer limits apply July through September; and fall, winter, and spring limits apply October through June. The rate of temperature change should not exceed 1°F per hour except when due to natural phenomena. Suggested temperatures are to prevail outside of established mixing zones as discussed in the section on zones of passage." (FWPCA, 1968)

The definition of the size of the passage zone is left to the proper administrative authority with the recommendation that the area, depth, and volume of water flow be sufficient (about 75 percent) to provide a usable and desirable passageway for fish and other aquatic organisms. Although the subcommittee recommends that the size of the mixing zone be minimized, this zone is implicitly written off for the survival of aquatic life.

On the basis of our review of readily available information on thermal tolerances of marine organisms and the operational experience of coastal power plants, we consider the thermal standards adopted are reasonable measures on the basis of present knowledge. Furthermore, we have arbitrarily selected any exposure to 90°F (32.2°C) as a boundary at which harmful biological effects (sublethal as well as lethal) are assumed to occur, to permit comparison of thermal discharges at the various sites. This appears to be valid except, perhaps, in the case of marine organisms that inhabit cold water only; it can be revised when additional information becomes available.

THERMAL TOLERANCES OF MARINE ANIMALS AND PLANTS

There are a number of bibliographies (Kennedy and Mihurshy, 1967; Raney and Menzel, 1969) and review articles available that contain information on thermal tolerances of aquatic organisms: Mayer (1914), Britt (1956, 1960, 1970), Gunter (1957), Johnson (1957), Kinne (1963, 1964), Bullard (1964), Wurtz and Renn (1965), TVA (1967), McWhinnie (1967), Mihurshy and Kennedy (1967), Welch and Wojtalik (1968), and Coutant (1968, 1969, 1970). Much of this information pertains to fresh water aquatic organisms, however. The book of Altman and Dittmer (1966), and the review articles of deSylva (1969) and Jensen et al (1969), are particularly valuable to this study because they contain summary tabular data on thermal tolerances of marine organisms retrieved from papers published in journals of many specialties. Much of this summary data has been incorporated into table 11.

It is important to note that the assembled data on thermal tolerances for the most part were not originally derived with the object of evaluating thermal effluents. Furthermore, experimental techniques and animals used by various biologists in obtaining the values differ greatly, so that results are not directly comparable even for the same species. It is prudent, therefore, that the numbers in general only be used as guides for qualitative evaluations. Quantitative evaluations of thermal effects will require experimental derivation of mortality rate coefficients for the various life stages of marine organisms under thermal regimes and environmental conditions that simulate the situations at power plant sites. Before mortality coefficients can be derived, however, the techniques for handling many important marine organisms in the laboratory will have to developed.

The thermal tolerance limits presented in table 11 have been generally given in terms of LD_{50} (lethal dose) or TL_m (median tolerance limit) by investigating biologists. These terms refer to the level of any intentionally imposed factor causing death of 50 percent of the total number of experimental animals per unit time (a convenient fixed interval such as 24, 48, or 96 hours is often used).

In some cases the value cited is the upper limit or lethal temperature and, in the case of phytoplankton, the values cited are temperatures that inhibit growth. The thermal tolerances in table 11 have been summarized for the major groups of organisms and are presented in table 12 in the order of decreasing thermal sensitivity. The intertidal, near-shore forms, including barnacles, corals, polychaetes, brown algae, echinoderms, and molluscs, are in the upper portion of the list. Ctenophores, green and red algae, phytoplankton, scyphozoans, copepods, fish, and chaetognaths, which are largely pelagic forms, appear in the lower part of the list. The highest thermal tolerance limit (53.7°C) is recorded for the barnacle (Chthalmus stellatus) a form normally occupying a habitat above mean high water. The lowest value (14.8°C) is listed for a fish, the California grunion (Leuresthes tenuis). The haddock (Melanogrammus aeglefinus) is another fish that has a rather low

Table 11. Thermal Tolerances of Various Marine Animals and Plants

Class	Species	Tolerance Limit (°C)	Time of Exposure (hr)	Acclimation Temperature (°C)	Size or Life Stage	Reference (p 122)
Chondrichthyes	Raja erinacea (little skate)	29.1-29.5	--	--	--	1
		30.2	--	--	juvenile	1
	R. ocellata (winter skate)	28.0	--	--	juvenile	1
	R. radiata (thorny skate)	26.5-26.9	--	--	juvenile	5
	Squalus acanthias (spiny dogfish)	28.5-29.1	--	--	--	1
Osteichythyes	Alosa pseudoharengus (alewife)	23.0	90	15	--	1
		26.7-32.2	--	--	--	1
		31.4	--	--	--	1
		29.0	--	--	egg hatching time 2 days	2
	Brevoortia tyrannus (Atlantic menhaden)	34.0	132	21	juvenile	3
		31.9	73	22	yearlings	3
	Clupea harengus (sea herring)	23.0	24	15.5	--	1
		20.8-24.7	--	--	juvenile-adult	1
		18.0	--	--	larva	1
		22.0-24.0	--	--	larva	1
		19.5-21.2	--	--	adult	1
		5.5	--	--	hatch time 20-34 d	1
	Fundulus heteroclitus (killifish)	34.0	--	20	--	4
		40.0	--	--	--	1
		37.0	--	28	--	1
		40.5-42.0	--	--	juvenile-adult	1
		25.0	--	--	hatching time 12 d	1
	F. parvipinnis	35.0	24	20	--	5
		37.0	24	30	--	5
	Gadus morhua (Atlantic cod)	19.8-24.4	--	--	adult	1
		14.0	--	--	hatching time 8.5 d	1
		10.0	--	--	embryo	5
	Girella nigricans (opaleye)	31.0	--	20,28	juvenile	5
		30.0	--	12	yearling	5
	Haemulon bonarience (black grunt)	35.0-40.0	--	--	--	1
	Hippoglossoides platessoides (Am. plaice)	22.1-24.5	--	--	--	1
	Leuresthes tenuis (California grunion)	14.8-26.8	--	--	--	1
		26.8	--	--	hatching time 9 d	1

Table 11 (Cont'd)

Class	Species	Tolerance Limit (°C)	Time of Exposure (hr)	Acclimation Temperature (°C)	Size or Life Stage	Reference (p 122)
Osteichthyes (cont'd)	Limanda ferruginea (yellowtail flounder)	24	--	--	--	1
	Lutjanus apodus (schoolmaster snapper)	35.0-40.0	--	--	--	1
	Macrozoarces americanus (ocean pout)	26.6-29.0	--	--	--	1
	Melanogrammus aeglefinus (haddock)	18.5-22.9	--	--	--	1
		14.0	--	--	hatching time 8.8 d	1
	Menidia menidia (Atlantic silverside)	22.5-32.5	--	--	adult	1
		22.0	--	--	hatching time 8-9 d	1
		< 32.0	24	--	adult	6
	Microgadus tomcod (Atlantic tomcod)	19.0-20.9	--	--	2 cm	1
		23.5-26.1	--	--	14-15 cm	1
		25.8-26.1	--	--	22-29 cm	1
	Mugil cephalus (striped mullet)	32.0	--	--	prolarvae, postlarvae	
	Myoxocephalus octodecemspinosus (sculpin)	28.0	--	--	--	5
	Oncorhynchus tschawytscha (chinook salmon)	21.5	168	5	juvenile	7
		25.1	168	20	juvenile	7*
	O. nerka (sockeye salmon)	22.2	168	5	juvenile	7
		24.8	168	20	juvenile	7
	O. keta (chum salmon)	21.8	168	5	juvenile	7
		23.7	168	20	juvenile	7
	O. gorbusha (pink salmon)	23.9	168	20	juvenile	5
		22.5	168	10	juvenile	5
		21.3	168	5	juvenile	5
	O. kitsutch (coho salmon)	22.9	168	5	juvenile	7
		25.0	168	20	juvenile	7*
	Osmerus mordax (American smelt)	21.5-28.5	--	--	--	1
	Pollachius virens (pollack)	28.0	--	--	--	1
	Pseudopleuronectes americanus (winter) flounder)	29.0	--	--	--	1
		27.9-30.6	--	--	--	1
		22.0-29.0	--	--	juvenile	1
		27.0	--	--	adult	1
		20.6	--	--	hatching time 15 d	1
	Marone saxatilis (striped bass)	32.0	--	--	adult	1
		17.9	--	--	hatching time 2 d	1

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*For reactions to temperatures warmer than 25°C, see Templeton and Coutant, 1970.

Table 11 (Cont'd)

Class	Species	Tolerance Limit (°C)	Time of Exposure (hr)	Acclimation Temperature (°C)	Size or Life Stage	Reference (p 122)
Osteichthyes (cont'd)	Scomber scombrus (Atlantic mackerel)	21.0	1	--	embryo	1
		21.0	1	--	hatching time 2 d	1
	Sphaeroides maculatus (northern puffer)	28.2-33.0	24	--	juvenile	1
	Tautoga onitis (tautog)	<31.0	1	--	adult	6
	Tautogolabrus adspersus (cunner)	29.0	1	--	--	1
		22.0	1	--	hatching time 1.7 d	
		29.0	summer	--	--	5
		25.0	winter	--	--	5
	Urophycis chuss (squirrel hake)	27.3-28.0	1	--	--	1
		15.6	1	--	hatching time 4 d	1
	U. tenuis (white hake)	24.5-25.2	1	--	hatching time 4 d	1
Thaliacea	Salpa africana	37.7	--	--	--	5
Ophiuroidea	Ophioderma brevispinum	40.5	9 min	--	--	5
		37.0	28 min	--	--	5
Ascidiacea	Asterias forbesi	42.0	9 min	--	--	5
		36.0	9 min	--	--	5
		32.0	43 min	--	--	5
	A. vulgaris	32.0	1° increase /5 min	20	--	5
Echinoidea	Arbacia punctulata	42.0	9 min	--	--	5
		38.0	45 min	--	--	5
		37.0	89 min	--	--	5
	Echinus microtuberculatus	39.1	--	--	--	5
	Lytechinus varigeatus	37.7	--	24.6-25.1	--	5
	L. anamesus	31.5	1	--	--	8
	Strongylocentrotus franciscanus	29.5	1	--	--	8
	S. purpuratus	29.5	1	--	--	8
	S. lividus	40.7	--	--	--	5
Chaetognatha	Sagitta elegans	25.5-27.5	1° increase /5 min	20	--	5
Merostomata	Limulus polyphemus	46.2	--	30	--	5
		41.0	--	22	--	5
		41.0	--	16	--	5

Table 11 (Cont'd)

Class	Species	Tolerance Limit (°C)	Time of Exposure (hr)	Acclimation Temperature (°C)	Size or Life Stage	Reference (p 122)
Malacostraca	Allorchestes littoralis	34.5-35.0	1° increase /5 min	20	--	5
	Asellus aquaticus	43.5	--	--	--	5
	Calliopius laeviusculus	26.7-29.7	1° increase /5 min	20	--	5
	Cancer irroratus	32.0-33.2	--	20	--	5
	Carcinus maenas	38.0	--	--	--	5
	Corophium volutator	36.5-37.5	1° increase /5 min	20	--	5
	Callinectes sapidus	38.7	48	30	adult	9
		36.9	48	22	--	9
		34.7	48	14	--	9
		33.1	48	6	--	9
		39.0	48	30	juv 40-60 mm	9
		39.0	48	--	juv 40-60 mm	9
		39.0	48	22	juv 40-60 mm	9
		35.3	48	14	juv 40-60 mm	9
		33.0	48	6	juv 40-60 mm	9
	Cragon septemspinosus	31.0-33.0	24	25-35	adult	10
		28.0	24	15	adult	10
		30.0-32.5	1° increase /5 min	20	--	5
	Gammarus locusta	32.2-34.8	--	20	--	5
	G. marinus	30.1-32.5	--	20	--	5
	G. roselii	36.0	--	--	--	5
	G. morroculodes	29.0	24	15	adult	10
	Homarus americanus	<26.0	sustained	--	--	11
		32	22 d	27.5	--	12
		29.5	--	25.0	--	5
		28.2	--	15	--	5
		22.1	--	5	--	5
		32.5	--	15	stage 3	5
		34.2	--	25	stage 4	5
		34.0	--	15	stage 4	5
		34.9	--	20	stage 5	5
		33.4	--	15	stage 5	5
	Menippe merinaria	32.7	sustained	30	egg hatching	13
	Mysis stenolepis	27.5-29.5	--	20	--	5
	Neomysis americana	31.0-33.0	24	25-35	adult	14
		25.0	24	15	adult	10
		16	24	1	adult	10
		20	24	5	--	10

Table 11 (Cont'd)

Class	Species	Tolerance Limit (°C)	Time of Exposure (hr)	Acclimation Temperature (°C)	Size or Life Stage	Reference (p 122)
Malacostraca (cont'd)	Orchomenella pinguis	27.5	1° increase /5 min	20	--	5
	Pagurus acadianus	29.6-32.0	--	20	--	5
	P. prideauxii	36.0	--	--	--	5
	Palaemonetes vulgaris	42.0	4 min	--	--	5
		37	9 min	--	--	5
		34	52 min	--	--	5
	P. intermedius	36.5	5 d	30	gravid female	13
		37.0	2 min	--	--	13
	Pandalus montagui	22.8-27.8	1° increase /5 min	20	--	5
	Paneus duorarum	30.9-31.9	sustained	30	nauplii	13
		~37.0	sustained	--	adult	13
	Palaemonetes pugio	35.0-38.3	24	25-35	adult	10
	Periclemenes americanus	34.2	5 d	30	adult	13
		37.0	2 min	--	--	13
	Panuilirus interruptus	38.0	sustained	--	--	11
	Pugettia producta	32.5	1	--	--	8
	Rhithropanopeus harrisi	35.0-38.3	24	25-35	adult	14
		33.0	24	15	adult	10
	Taliepus nuttali	32	1	--	--	8
	Uca pugilator	46.0	5 min	--	--	5
		41.0	18 min	--	--	5
		40.0	82 min	--	--	5
Cirripedia	Balanus balanoides	45.3	--	--	--	5
	B. perforatus	47.0	--	--	--	5
	Chthamalus stellatus	53.7	--	--	--	5
	Eliminus modestus	49.5	--	--	--	5
	Lepas fasicularis	42.3	--	29	--	5
Copepoda	Acartia tonsa	35.0	3	25	adult	15
		>30.5	brief	--	--	10
	Calanus finmarchicus	26.5-29.5	1° increase /5 min	20	--	5
	Eurytemora affinis	30.0	12	25	adult	10
Branchipoda	Alonia affinis	40.5	--	--	--	16
	Eurycercus lamellatus	35.0	--	--	--	16

Table 11 (Cont'd)

Class	Species	Tolerance Limit (°C)	Time of Exposure (hr)	Acclimation Temperature (°C)	Size or Life Stage	Reference (p 122)
Polychaeta	Eunice fucata	42.7	--	29	4-5 d old	5
	Hydroides dianthus	>30.0	31 d	--	adults	17
		>32.0	7	--	larvae	18
	Tomopteris catharina	31.6	1° increase /5 min	20	--	5
Cephalopoda	Octopus vulgaris	36.0	--	--	--	19
Pelecypoda	Astarte undata	33.5	1° increase /5 min	15	--	5
	Cardita borealis	31.6	--	15	--	5
	Caridum pinnulatum	33.2	--	15	--	5
	Crassostrea virginica	47.5	rapid inc.	24	--	5
		41.0	slow inc.	24	--	5
		48.5	--	--	adults	19
		33.0	8	27	egg and larva	20
	Gemma gemma	35.0-38.3	24	25-35	adult	14
	Hiatella rugosa	32.8	1° increase /5 min	15	--	5
	Macoma balthica	42.3	--	15	--	5
	Mercenaria mercenaria	45.2	--	15	--	19
	Modiolus modiolus	36.3	--	15	--	5
	Musculars discors	31.9	--	15	--	5
	M. nigra	34.9	--	15	--	5
	Mya arenaria	40.6	--	15	--	19
		31.0-33.0	24	25-35	adult	14
	Nuculana tenuisulcata	31.5	1° increase /5 min	15	--	5
	Mytilus edulis	40.8	--	--	adult	19
		28.0	20-100	variable	adult	6
	Pandora trilineata	33.5	1° increase /5 min	15	--	5
	Placopecten magellanicus	23.5	--	summer	--	5
	Spisula solidissima	37.0	--	nat. water	--	
				15	--	5
	Yoldia sapotilla	34.8	--	15	--	5
	Zirfoea crispata	35.5	--	15	--	5
Gastropoda	Astrea undosa	35.0	sustained	--	--	8
	Buccinum undatum	29.0	--	--	--	5
	Littorina littoralis	44.3	--	--	--	5

Table 11 (Cont'd)

Class	Species	Tolerance Limit (°C)	Time of Exposure (hr)	Acclimation Temperature (°C)	Size or Life Stage	Reference (p 122)
Gastropoda (cont'd)	Littorina littoralis	44.3	1° increase /5 min	--	--	5
		41.0	--	low tide	--	5
		43.5	--	mid tide	--	5
		43.7	--	high tide	--	5
	L. neritoides	46.3	1° increase /5 min	--	--	5
	L. palliata	41.8	--	low tide	--	5
		42.2	--	mid tide	--	5
		42.5	--	high tide	--	5
	L. rudis	45.0	1° increase /5 min	--	--	5
		42.4	--	low tide	--	5
		43.0	--	mid tide	--	5
		43.2	--	high tide	--	5
	Nassarius obsoletus	46.0	lethal 5 min	--	--	5
		43.0	lethal 9 min	--	--	5
		42.0	lethal 27 min	--	--	5
		41.0	survived 1-2	--	--	5
	Norrisia norissii	34.5	sustained	--	--	8
	Haliotis corrugata	35.0	sustained	--	--	8
	H. rufescens	33.0	sustained	--	--	8
	Patella athletica	41.7	1° increase /5 min	--	--	5
	P. vulgata	42.8	--	--	--	5
	P. depressa	43.3	--	--	--	5
	Tellina tenuis	32.6	sustained	14-15	larvae	21
	T. fabula	32.6	sustained	--	larvae	21
	Thais lapillus	35.0-35.5	--	--	--	5
Nuda	Beroe cucumis	29.7-30.0	--	14	--	5
	B. ovatus	40.0	sudden	--	--	5
		36.4	sudden	--	--	5
Anthozoa	Anemonia sulcata	40.9	--	--	--	5
	Favia fragum	37.1	--	--	--	5
	Meandra accolata	36.8	--	--	--	5

Table 11 (Cont'd)

Class	Species	Tolerance Limit (^oC)	Time of Exposure (hr)	Acclimation Temperature (^oC)	Size or Life Stage	Reference (p 122)
Anthozoa (cont'd)	Porites astraeoides	35.8	--	--	--	5
	P. clavaria	36.4	--	--	--	5
	P. furcata	36.8	--	--	--	5
Scyphozoa	Aurelia aurita	38.5	--	29	--	5
		30.0	--	14	--	5
	Chrysaora quinquecirrha	34.3	24	--	medusae	14
		35.0	24	15	medusae	10
	Cyanea artica	26.8-28.0	--	14	--	5
	Pleurobrachia pileus	<26.0	--	--	--	16
Hydrozoa	Pennaria tiarella	34.7	--	22-26	--	5
Chlorophyceae	Enteromorpha compressa	35.0	12	--	--	22
	Rhizoclonium hookeri	35.0	--	--	--	5
	Ulva lactuca	30.0	--	--	--	5
		35.0	--	--	--	5
	Valonia macrophysa	31.2±0.2	3 d	23	adult	13
	Penicillus capitatus	31.0	5 d	23	adult	13
	Dictyosphera cavernosa	33.0-34.0	sustained	23	adult	13
	Chalmydomonas sp (Y)^{2}	32.0-35.0	--	--	--	24
	Chlorella sp (UHMC)^{2}	32.0-35.0	--	--	--	24
	Dunaliella euchlora^{2}	39.0	--	--	--	24
	Nannochloris (582)^{1}	40.0	--	--	--	23
	Platymonas sp (#1)^{2}	35.0	--	--	--	24
	Protococcus sp (T3)^{2}	26.0	--	--	--	24
	Protococcus sp (T9)^{2}	35.0	--	--	--	24
Bacillariophycea	Chaetoceros (581)^{1}	41.0	--	--	--	23
	Detonula confervacea^{2}	16.0	--	--	--	25
	Melosira sp^{2}	27.0-30.0	--	--	--	24
	Nitzchia laevis^{2}	30.0	--	--	--	24
	Phaeodactylum tricornutum^{2}	29.0-35.0	--	--	--	24
Chrysophyceae	Isochrysis galbana^{2}	27.0-35.0	--	--	--	24
	Monochrysis lutheri^{2}	29.0-35.0	--	--	--	24
Cinophyceae	Grymnodimium (581)^{1}	32.0	--	--	--	23
	Gymnodimium (582^{2})	34.0	--	--	--	23

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1. Upper temperature limit 2. No growth

Table 11 (Cont'd)

Class	Species	Tolerance Limit (°C)	Time of Exposure (hr)	Acclimation Temperature (°C)	Size or Life Stage	Reference
Isogeneratae	Dictyota dichotoma	27.0	--	--	--	5
		32.0	--	--	--	5
	D. divaricata	32.0	--	--	--	5
	Pylaiella littoralis	30.0	--	--	--	5
Cyclosporeae	Ascophylum nodosum	39.3-41.5	--	--	--	5
	Fucus serratus	39.0-40.7	--	--	--	5
	F. vesiculosus	41.6-42.5	--	--	--	5
		41.9	--	--	--	5
Bangiophyceae	Porphyra umbilicans	30.0	--	--	--	5
Florideae	Callithamnion hookeri	30.0	12	--	--	5
	Polysiphonia elongata	27.0	12	--	--	5
	P. ferrulacea	35.0	12	--	--	5
Hydrocharitaceae	Thalassia testudium (turtle grass)	33.0	sustained	23	--	28
Potamogetonaceae	Ruppia maritima (marsh grass)	<35.0	sustained	--	--	27
	Potamogeton perfoliatus	<45.0	--	25-35	--	28

References

1. deSylva (1969)
2. Edsall (1970)
3. Lewis and Hettler (1968)
4. Spector (1956)
5. Altman and Dittmer (1956)
6. Pearce (1969)
7. Brett (1952)
8. North and Shaefer (1964)
9. Tagatz (1969)
10. Mihursky and Kennedy (1967)
11. Wright (1965)
12. McLeese (1956)
13. Bader et al
14. Mihursky (1969)
15. Heinle (1969)
16. Jensen et al (1969)
17. Leone (1970)
18. Gaucher et al (1967)
19. Gunter (1957)
20. Kennedy et al (1969)
21. Barnett and Hardy (1969)
22. Biebl (1962)
23. Thomas (1966)
24. Ukeles (1961)
25. Smayda (1969)
26. Thomas (1966)
27. Roesler and Zieman (1969)
28. Anderson (1969)

thermal tolerance limit (18.5°C). The killifish (Fundulus heteroclitus) exhibits a high thermal tolerance (42°C). Three common plankton forms, Calanus finmarchicus (copepod), Gymnodinium sp. (dinoflagellate), and Chaetoceros sp. (diatom), all cosmopolitan species, are cited as having thermal tolerance limits of 26.5 to 29.5°C, 32° to 34°C, and 41°C, respectively. Of the 22 groups of organisms represented in table 12, 17 have mean tolerance limits between 30° and 40°C, three have tolerance limits above 40°C, and only two have thermal tolerance limits below 30°C.

Table 12. Thermal Tolerances of Various Groups of Marine Organisms (Based on Values in Table 11)

	Mean (°C)	Range (°C)	Number of Values
Cirripedia	47.6	42.3-53.7	5
Merostomata	42.7	41.0-46.2	3
Gastropoda	40.8	29.0-46.0	27
Branchipoda	37.8	35.0-40.5	2
Thaliacea	37.7	37.7	1
Sea grasses	37.6	33.0-45.0	3
Anthozoa	37.3	35.8-40.9	6
Polychaeta	37.1	30.0-42.7	3
Phaeophyceae	37.0	27.0-42.5	11
Echinodermata	36.3	29.5-40.7	17
Cephalopoda	36.0	36.0	1
Pelecypoda	36.0	23.5-48.5	25
Hydrozoa	34.7	34.7	1
Nuda	34.0	29.7-40.0	4
Chlorophyceae	33.2	30.0-35.0	8
Malacostraca	32.9	16.0-46.0	62
Phytoplankton	32.2	16.0-41.0	22
Scyphozoa	31.2	26.0-38.5	7
Rhodophyceae	30.5	27.0-35.0	4
Copepoda	30.3	26.5-35.0	5
Fish	28.6	14.8-42.0	53
Chaetognatha	26.5	25.5-27.5	2

OPERATING EXPERIENCE WITH POWER PLANTS

Before evaluating probable thermal effects at the sites selected, it is instructive to examine past experience at operating power plants. Synopses of the operating experience of some power plants in estuarine and coastal waters are given in tables 13 through 16.Related studies on river or lakes are listed in table 17. A review of these studies and the publications of Naylor (1965), Warriner and Brehmer (1966), Adams (1969), and Hechtel (1970), indicate that the following adverse ecological effects have occurred from power plant influences:

1. A reduction in the photosynthetic capability of entrained plankton.
2. Total mortality of many species of entrained zooplankton.
3. A reduction in the quantity of aquatic plants or epibenthic algae in the immediate vicinity of the discharge.
4. Lower diversity indices of plant-animal communities in the immediate vicinity of the discharge with thermally tolerant undesirable species sometimes succeeding the desirable species.
5. An increase in the quantity of fouling organisms in the immediate vicinity of the discharge, and unseasonable reproduction of some fouling organisms.
6. Severe mortality of fish (by impingement on screens) if water intakes are not carefully designed.

The operating experience of power plants indicates, in general, that adverse effects, where they occur, are highly localized and seasonal. Each plant site must be examined individually to assess the relative effect. Results of additional studies now underway should help provide the information needed for predicting the extent and severity of power plant discharge effects on life.

THERMAL REGIMES AT THE SITES STUDIED

The pelagic biota at all of the four sites selected can be subjected to thermal effects by: (1) passage through the condenser with the cooling water, (2) involuntary entrainment into the discharge water jet, and (3) swimming voluntarily into the mixing zone. The time-temperature profile the biota experiences

Table 13. Patuxent Estuary -- Operating Experience*

Number of power plants	2
Rated capacity	355 Mw each
Cooling water	250,000 gpm each
Temperature rise	11.5 to 23°F
Ambient summer temperature	84-90°F
Phytoplankton	68-94% reduction in photosynthetic capability from entrainment during summer and fall (chlorine contribution possible). No recovery within four hours of passage. Effect on standing crop indeterminate and being studied further Primary production of organisms in the cooling water reduced 91%
Aquatic plants	*Ruppia maritima* population reduced in area of effluent discharge *Potamogeton perfoliatus* population increased
Zooplankton	Copepod mortalities 100% from entrainment (chlorine contribution probable). Mortality of sea nettles, also. Standing crop of *Acartia tonsa* and other estuarine copepods not reduced. Standing crop of ctenophores and sea nettles (jellyfish) reduced
Fish	Winter attraction to warm effluent with movement away during the summer White perch population remained constant, striped bass population increased, while white catfish and hogchokers decreased in abundance. Decline of hogchoker and catfish possibly caused by entrainment of larval stages and entrapment of juveniles and adults on intake screens Indication of a decrease in diversity indices of fish species Effect on standing crop of fish eggs or larvae indeterminate at this time
Benthic organisms	
Opossum shrimp	Effect on standing crop indeterminate at this time
Soft-shell clam	Effect on standing crop indeterminate at this time
Oyster	No important effect on growth, mortality or condition in oyster beds. When placed in effluent canal 100% mortality and "greening" occurred (mortality possibly caused by copper rather than thermal influences)

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*Mihursky (1969), Morgan and Stross (1969), Heinle (1969), Cory and Nauman 1969), Nauman and Cory (1969), Rosenburg (1969), Hamilton, et al (1970).

Table 13 (Continued)

Fouling organisms	Increase in standing crops and production at effluent station over the intake. Earlier spring sets of certain organisms and unseasonable set of barnacles

Table 14. Biscayne Bay, Turkey Point -- Operating Experience*

Number of power plants	2 (2 additional nuclear plants proposed, 760 Mw each)
Rated capacity	432 Mw each
Cooling water	286,000 gpm each
Temperature rise	5°C
Ambient summer temperature	30-31°C
Phytoplankton	?
Aquatic plants	Thalassia (turtlegrass) population killed or reduced within +4°C discharge isotherm. Species diversity index of macro-algae reduced within +3°C isotherm. Replaced by a blue green and filamentous algal mat
Zooplankton	EPA (WQO) National Marine Water Quality Laboratory conducting studies
Fish	Fewer species and numbers of fishes in area of discharge
Benthic organisms	
Crustaceans	Fewer crustaceans in area of discharge but greater numbers within +3°C isotherm
Molluscs	Fewer molluscs in area of discharge but greater numbers within +3°C isotherm
Fouling organisms	Settling of benthic fouling organisms, including oysters, inhibited during summer in effluent canals but settlement occured during winter

*Bader et al, Roessler and Zieman (1969), Ferguson Wood and Zieman, 1969 Nugent (1970)

Table 15. San Francisco Bay, Contra Costa Plant -- Operating Experience*

Rated capacity	1298 Mw
Cooling water	845 cfs
Temperature rise	16°F
Ambient summer temperature (surface)	45-74°F
Phytoplankton	?
Aquatic plants	?
Zooplankton	?
Fish	Intake design and velocity very important in preventing fish kills. Juvenile salmon suffered no mortality after passage through the condenser, with a ΔT 25°F exposure for 10 min, when held afterwards for 10 days Juvenile striped bass survival was 94% after passage and 5-day holding period No information on survival of eggs or larvae passing through condensers, but mortaility was 100% when impinged on screens
Benthic organisms	?
Fouling organisms	?

*Adams (1968, 1969), Kerr (1953).

Table 16. California Coast, Morro Bay -- Operating Experience**

Rated capacity	1000 Mw
Cooling water	1050 cfs
Temperature rise	20°F
Ambient summer temperature	48-62°F
Phytoplankton	?
Aquatic plants	Algal abundance and diversity diminished for approximately 200 meters from discharge canal

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**North (1969), Adams (1968)

Table 16 (Continued)

Zooplankton	?
Fish	Striped bass (*Roccus sexatilis*) and opaleye (*Girella nigricans*) present in discharge canal
Benthic or epibenthic organisms	Abundance and diversity diminished for approximately 200 meters from discharge canal. Less severely affected than flora. Sea anemones abundant in discharge canal. Limpets (Acmaea), snail (Tegula), and crab (Pugettia) present in canal Pismo clams, immediately north of plant, not harmed Cold water flora and fauna replaced by warm water species
Fouling organisms	?

Table 17. Related Fresh Water Studies on Thermal Discharges

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will differ in each case but will be most severe in the case of passage through the condensers in the absence of water currents that disperse the thermal plume. Benthic organisms on or in the bottom will not ordinarily be subjected to thermal effects, as the jet discharge will not contact the bottom. Unusual current conditions might occasionally expose them to the thermal discharge, however.

The thermal characteristics of the waters during the summer and winter at the four sites examined are given in table 18. On the basis of ambient water temperature at a depth of approximately 250 ft, the southeastern Florida, southern California, and New York Bight/Gulf of Maine sites represent waters of distinct thermal characters. Surface water temperatures in the southeastern Florida region are the warmest, yet undergo the least winter-summer temperature change (5^oF); Atlantic waters off the northeast coast are the coldest, but show the greatest winter-summer temperature change

Table 18. Thermal Characteristics of Water at the Four Sites Studied, Under Warmest Conditions Recorded

Site	Intake Ambient Temperature		Condenser Maximum Temperature		Surface Ambient Temperature		Surface Field Present	
	W	S	W	S	W	S	W	S
Florida	78	76	103	101	80	85	yes(2)*	no
New York Bight	50	52	75	77	50	75	yes(3)*	no
Gulf of Maine	47	50	72	75	47	66	yes(3)*	no
California	61	58	86	83	66	77	no	no

Temperature in °F

W-winter, S-summer

*max °F above ambient temperature

(25°F). Maximum water temperatures attained in passage through the condenser at the four sites may exceed local summer surface temperatures by 2 to 15°F momentarily, depending on location. Because of thermal stratification, the thermal plume does not reach the surface at any of the sites during the summer. This is also true for southern California during the winter. When the plume does reach the surface in winter, the maximum temperature exceeds ambient by 3°F, at most.

Waters off Southeastern Florida

The maximum time-temperature exposure profile of organisms passing through the condenser at the southeastern Florida site is shown by figure 16, p 87. The figure indicates that organisms are subjected to a temperature of 25°F above the intake ambient for a period of 24 sec. During the summer, the temperature at the plume centerline reaches ambient temperature of the sea within 59 seconds. During the winter, the thermal plume reaches the surface in approximately 103 sec at a temperature less than 3°F above ambient.

Superimposing these results on the data in table 18, the figures indicate that organisms in the cooling water will be subjected to temperatures greater than 90°F for 37 sec during the summer and a maximum of 101°F for 24 sec. During the winter, organisms will be exposed to temperatures greater than 90°F for 41 sec, with a maximum temperature of 103°F (39°C) for 24 sec. Also, entrained organisms will be pumped from a temperature stratum of 76°F and placed in a temperature stratum of 84°F during the summer, a change of 8°F in less than one minute (see temperature profile, figure 14, p 85.) During the winter, entrained organisms will be extracted from an ambient temperature of 78°F and jetted to an ambient surface temperature of 80°F in about two minutes.

The thermal fields projected in section 5 show that the volumes of water bounded by the summer and winter mixing zones are both approximately 2×10^5 ft^3, which is very small. Although the plume will move about under the influence of currents, this volume of water is the maximum amount that will be subjected to sustained temperatures greater than the standards selected in the analysis.

The New York Bight

The maximum time-temperature exposure profile of organisms passing through the condenser in this region is shown by figure 21, p. 93. As at all sites, this figure again indicates that organisms will be exposed to a temperature of 25°F above ambient for 24 sec. During the summer, ambient sea temperature is attained in 59 sec. During the winter, the thermal plume forms a surface field in 96 sec. The maximum temperature at the surface is less than 3°F above ambient.

Using ambient temperatures given in table 18, the figure shows that entrained organisms will be subjected for 24 sec to maximum temperatures of 77°F during the summer and 75°F during the winter, while passing through the condenser. Organisms during the summer will be removed from a temperature stratum of 52°F and jetted to a temperature stratum of 55°F in less than a minute (see temperature profile, figure 19, p 91). During the winter, the water is isothermal at 50°C from the surface to a depth of 250 ft, and the plume reaches the surface at a temperature less than 3°F above ambient.

The additional volumes of water entrained in the water jet after discharge from the condenser are shown by figure 21. Because of the temperate absolute temperature reached, adverse biological effects should be minimal.

The thermal fields projected in section 5 show that the volumes of water in the summer and winter mixing zones are approximately 4×10^5 and 3×10^5 ft^3, respectively.

The Gulf of Maine

The thermal regime predicted for the Maine area is shown by figure 18. Since the regime is almost identical to that of New York Bight, except for slightly lower summer and winter temperatures, the thermal regime will not be discussed further.

Waters off Southern California

Figure 24 shows the maximum time-temperature exposure profile of organisms passing through the condenser in waters off the southern Californian area. The data indicate that ambient temperatures are attained in a little over a minute during both summer and winter. Organisms will be jetted from an ambient temperature of 58°F to 66°F in 88 sec in winter (see thermal profile in figure 23, page 94). The maximum temperature that entrained organisms will be exposed to in summer and winter are 83° and 86°F respectively. These temperatures will occur for 24 sec during passage through condensers.

The thermal fields projected in section 5 show that the volume of water is about 3.5×10^5 in the summer mixing zone and 2×10^5 ft^3 for the winter mixing zone.

POTENTIAL BIOLOGICAL EFFECTS OF PROJECTED THERMAL DISCHARGES

From a biological standpoint, the most important findings of the thermal regime analysis are these:

1. Entrained organisms will face maximum temperatures exceeding 90°F only in southeastern Florida, where they will be exposed to temperatures hotter than 90°F both summer and winter for about 40 sec, and temperatures of 101°F to 103°F for 24 sec, at a flow rate of 600,000 gpm.
2. Entrained organisms will undergo rapid, marked, and sustained temperature changes, in addition to that produced by passage through condensers, in two instances. One will occur in southeastern Florida during the summer, where organisms living in waters at 76°F will be jetted to waters of 84°F in a matter of a minute. The other occurs in southern California during the summer, where organisms living in water of 58°F will be jetted to water of 66°F or more in about 78 sec.
3. Temperature drops off very rapidly once the water leaves the condenser.
4. Thermal effects from entrainment are minimal at the Maine and New York Bight sites, the regions of coldest water.
5. The projected volume of the mixing zone is quite small, and moves away from the bottom so that benthic organisms are not exposed to the thermal plume.

Organisms passing through condensers of many operational power plants are commonly subjected to potentially toxic substances as well as to heat. Some power plant operators deliberately add chlorine to control slime buildup and fouling organisms within the condenser tubing. There is no doubt that chlorine is harmful biologically; otherwise it would not be used to control growths in condenser tubing. Various cleaning chemicals or detergents are also used ocasionally to clean condenser walls, and other chemicals may be used as corrosion inhibitors or to regenerate resin beds. Toxic materials, such as copper, can be leached from materials of construction or from antifouling paints used to protect structures. The toxicity of copper to many plants and animals, at a level of about 0.05 ppm, is well known. It is difficult to state what the situation would be with an underwater power station, as the design at this stage is conceptual and actual operating procedures and materials of construction are not defined. Toxic substances might be kept to minute traces if the design of the plant were so directed. For instance, reversal of flow through condensers is feasible and has been successfully applied in some plants, for the control of fouling, and mechanical devices are available for keeping condenser tubing clean. Thus, operating procedures and design specifications might adopt such principles to circumvent potential pollution.

Organisms are also subject to turbulent shear when pumped through the condensers. To our knowledge, the importance of this stress to marine organisms has not been investigated. Some small organisms (1-10 microns) apparently are not harmed, since the fermentation industries vigorously agitate fungi to maintain highly aerobic conditions in some of their processes, and algae such as Chlorella have been pumped without any apparent harm. Juvenile fish have also been passed through coastal power plants without adverse effect.

In view of the potential biological harm that might be caused by entrainment, it is of interest to view the power plant as a predator, and conduct some hypothetical calculations on the ecological effect, assuming that either 100% or 5% of the entrained organisms are killed.

In order to estimate the potential effect of a single power station on the population of some planktonic organisms, the condenser "kill rate" has been calculated and compared with the normal mortality rate for a few species of phytoplankton and zooplankton.

The condenser kill rate (CKR) is given by the following equation:

$$\mathrm{CKR} = f_k \times C_l \times Q, \text{ number of plankton per unit time} \tag{1}$$

where C_l = local plankton concentration, number per unit volume
Q = flow rate of condenser cooling water, volume per unit time
f_k = fractional kill per pass

Uniform mixing by adequate circulation over the geographical range of interest is assumed so that the plankton concentration is not locally depleted. This is a cautious assumption in terms of its effect on the total population of a specific organism. To estimate the normal mortality rate for a specific planktonic organism, we need only assume that a certain time-average steady-state population level has been attained for that organism. Then we can set the normal mortality rate (NMR) equal to the mean reproduction rate (MRR) in accordance with the following expression:

$$\mathrm{NMR} = \mathrm{MRR} = K \times C_m \times V, \text{ number of plankton per unit time} \tag{2}$$

where K = exponential growth constant, time $^{-1}$
$= \dfrac{0.693}{\text{doubling time}}$
C_m = mean concentration, number per unit volume
V = volume of sea water contained in assumed geographical range of the species

A kill ratio (KR) is then defined as:

$$\mathrm{KR} = \frac{\mathrm{CKR}}{\mathrm{NMR}} = \frac{f_k \times C_l \times Q}{K \times C_m \times V} \tag{3}$$

Because uniform mixing was assumed, $C_l = C_m$

and $$\mathrm{KR} = \frac{f_k Q}{KV} \tag{4}$$

Hence, the kill ratio becomes independent of the plankton concentration.

This approach was applied to the proposed New York Bight site, and kill ratios were calculated for a typical phytoplankton (Skeletonoma costatum) and two zooplankton (Centropages typicus, Pseudocalanus minutus), based on a power plant water intake rate of 1355 cu ft/sec, and generation (doubling) times of 13 hr for the phytoplankton (Fogg, 1965) and 0.33 yr for the zooplankton (Deevey, 1952). The following expressions were obtained:

$$KR = \frac{9.15 \times 10^{7} f_k}{V} \quad \text{(phytoplankton)} \qquad (5)$$

$$KR = \frac{2.02 \times 10^{10} f_k}{V} \quad \text{(zooplankton)} \qquad (6)$$

These are plotted in figures 27 and 28 for f_k values of 0.05 and 1.0. For ease of comprehension, the original abscissa units of offshore volume were converted into offshore area, based on mean depths of 75 ft for the phytoplankton population and 200 ft for the zooplankton. The graphs show that both the phytoplankton and zooplankton populations suffer a negligible increase in their mortality rates when their total range of occurrence (15,000 to 40,000 sq mi) is considered. For the condenser kill ratios to become detectable, based on an assumed threshold of detectability of 10 percent, their geographic ranges would have to be restricted to areas of less than 0.4 sq mi for the phytoplankton, and less than 35 sq mi for the zooplankton. At this point, however, the effect of coastal currents should be considered, and they would probably depress the kill ratio by at least an order of magnitude.

The maximum quantity of dead plankton produced per power plant will be approximately 42,500 cu ft (1400 tons) per year, based on an f_k of 1.0, and a plankton density of 1.0 cc/m^3. The rate of deposition will, of course, be a function of local velocity distributions (horizontal and vertical) and turbulence at the site, as well as the manner in which the condenser effluent is discharged. The zooplankton will, in general, settle about twice as fast as the phytoplankton with a far greater deposition rate. Assuming a net current speed of 1 knot and an average settling velocity of 200 ft/hr for the zooplankton (Sverdrup, 1942; Grice and Hart, 1972), settling areas of at least 0.1 sq mi should be produced with deposition rates of less than 1 cm per year, if no consumption of the dead plankton is assumed.

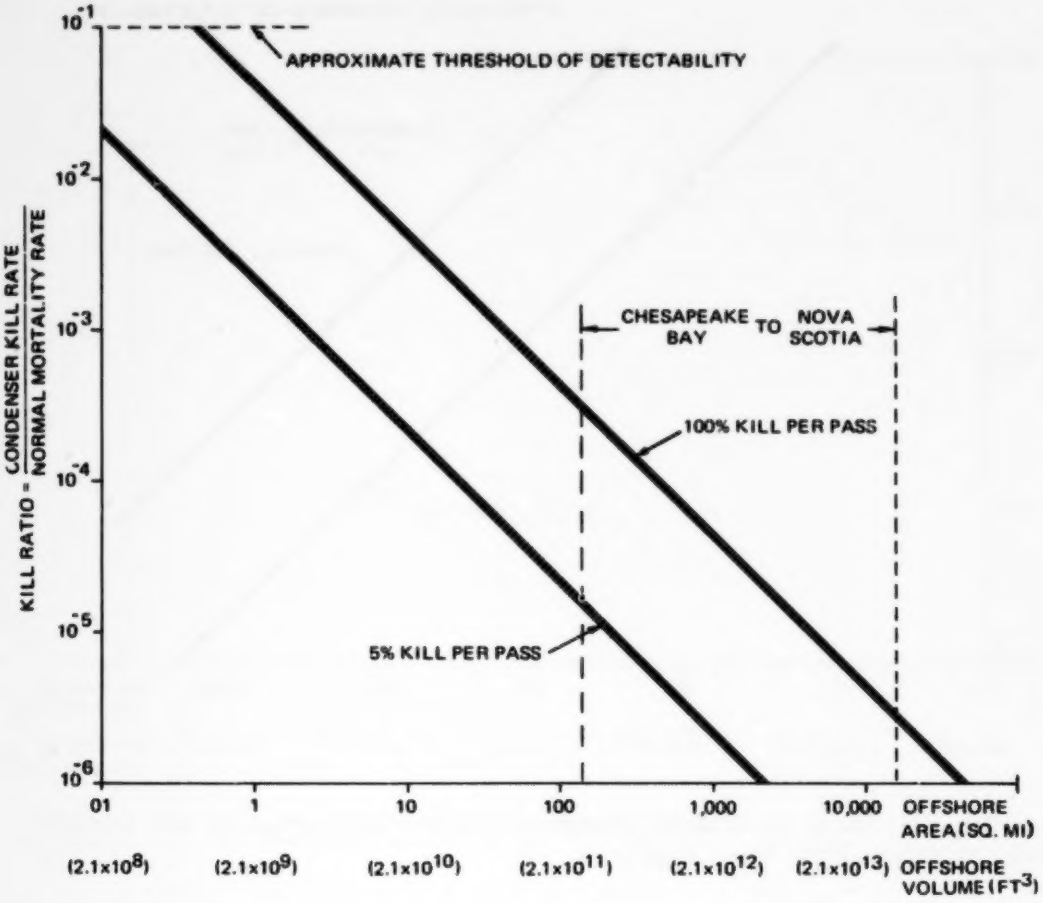

Figure 27. Kill Ratio vs Coastal Range of Skeletonema costatum (New York Bight)

An alternate method for estimating the effect of entrainment on plankton populations, which might be more appropriate for the Florida site, is to relate the local plankton "consumption" rate to the natural population drift past the site due to coastal currents. The kill ratio is then defined as:

$$KR = \frac{f_k \times C_l \times Q}{C_m \times Q_o} \tag{7}$$

where Q_o is the net offshore flow past site, cu ft/day. With the assumption of uniform mixing in the plane perpendicular to the coastal drift, equation (7) becomes:

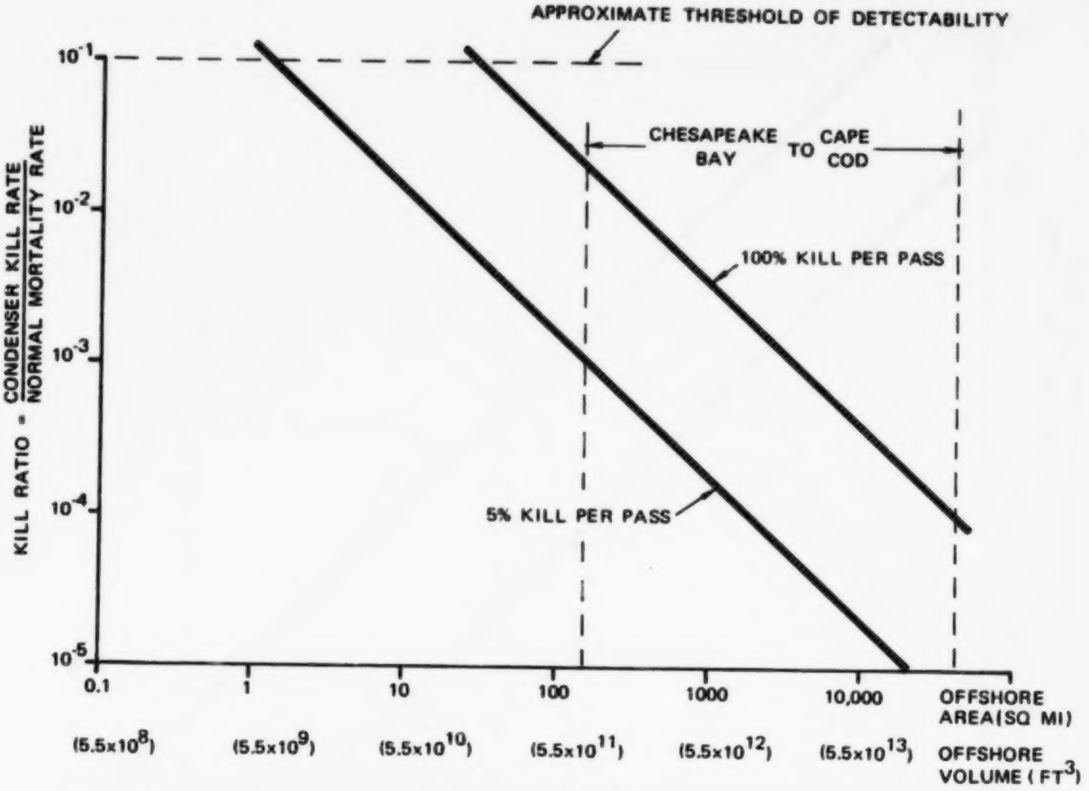

Figure 28. Kill Ratio vs Coastal Range of *Centropages typicus* and *Pseudocalanus minutus* (New York Bight)

$$KR = \frac{f_k Q_r}{Q_o} = 11.7 \times 10^7 \frac{f_k}{Q_o} \qquad (8)$$

Figure 29 shows a plot of KR vs Q_o at values of 0.05 and 1.0 for f_k. The magnitude of the net offshore drift past the proposed Florida site has been estimated at 2.5×10^{13} cu ft/day (Sverdrup, 1942), based on the velocity distribution and water mass in a 100-meter deep section through the narrowest part of the Straits of Florida between Fowey Rocks and Gun Cay. At this flow, the corresponding kill ratio at an f_k of 1.0 is only 4.7×10^{-6}, indicating that hypothetically 10,000 power plants could be installed in the vicinity of the proposed site before a measurable (10 percent) kill ratio is produced.

The calculations show that the effect of entrainment on the total plankton population levels will be insignificant. However, the assumption of uniform mixing must be investigated. Organisms that reproduce slowly and are restricted in distribution appear to be the forms most subject to extinction if entrainment effects are severe.

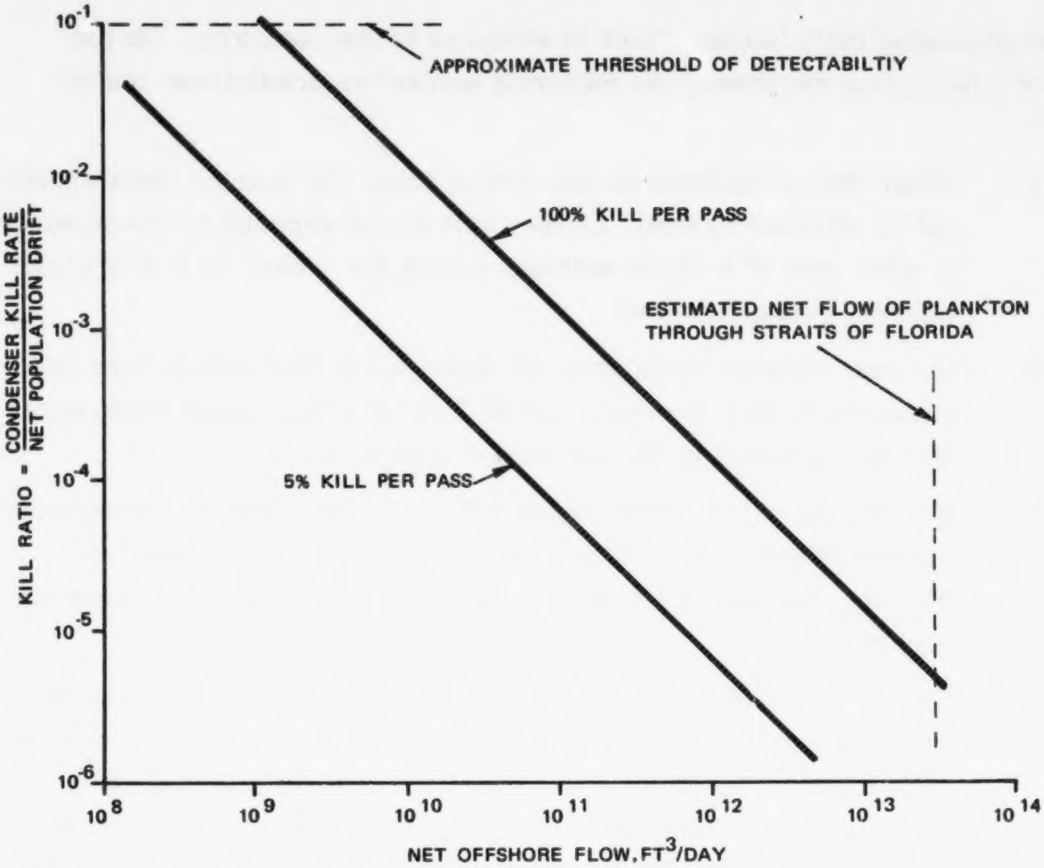

Figure 29. Kill Ratio vs Net Offshore Flow -- Southeastern Florida Site

Perusal of table 11 indicates that reactions of organisms exposed to the temperature regimes projected for the four sites have not been investigated. However, the information generally shows that many organisms, except "cold water" forms, remain viable when exposed to temperatures of approximately 90°F for many hours. The thermal regimes predicted through entrainment for southeastern Florida both during the summer and winter, and southern California during the summer, present situations of greatest potential thermal stress to the biota. Acclimation to the temperatures projected is impossible because water temperature is increased 25°F over the ambient in less than a minute during condenser passage, and organisms are jetted within a few minutes to a temperature stratum 8°F over ambient, where they remain. Since organisms are not naturally subjected to the rapid temperature changes predicted for these sites, we must assume that entrained organisms will be harmed physiologically, unless there is evidence to the contrary. On the basis of information reviewed, the following subjective predictions can be made:

1. Other than organisms in the mixing zone, the marine biota should not be affected by heat, as they will not be exposed to temperatures greater than 4°F above ambient during the winter or 1.5°F above ambient during summer.

2. Because pelagic organisms are distributed everywhere over the continental shelf to depths of 250 ft at all sites, many organisms will be entrained in the condenser cooling water.

3. Positioning of the intake below 200 ft should minimize entrainment of phytoplankton at all sites, except perhaps in southeastern Florida, because the intake of the plant will be situated below the euphotic zone.

4. The diatoms entrained should survive, but their photosynthetic capacity may be lowered. Dinoflagellates and nanoplankton generally should react similarly, but there is little information on which to base a judgment. The largest numbers of diatoms will be entrained in the early spring; dinoflagellates during the summer. Diurnal fluctuations in the numbers of dinoflagellates entrained may occur.

5. Because of high reproductive rates, sporulation capacity, and wide geographical distribution of phytoplankton, the probability of depleting populations of phytoplankton species is very low -- the lowest of all groups surveyed.

6. The number of various zooplankton entrained will vary diurnally, seasonally, and yearly. The greatest numbers will be entrained in spring and the fewest during winter. The young stages of most pelagic organisms will be encountered during late spring and early summer. Seasonal differences in the biomass of the zooplankton entrained should be greatest in Maine and least in southeastern Florida.

7. Mortality through entrainment of larval and adult stages of holoplanktonic zooplankton can be anticipated. The mortality of large soft organisms such as siphonophores or salps, which cannot withstand large shear forces, should be more severe than forms possessing tough integuments such as copepods and euphausiids.

8. Some meroplanktonic larval forms of benthic organisms will also be killed, but fewer species should be entrained than at coastal stations, because fewer species live at depths of 250 ft.

9. Phytoplankton and zooplankton diversity indices at all sites should remain unchanged, because of rapid heat dissipation by dilution and water transport by currents.

10. Juvenile fish and fish eggs should suffer little damage by passage through the condensers. Larval fish that are entrained may suffer severe mortality. Maximum numbers will be entrained in late spring and early summer as the spawned eggs hatch, and during daylight hours, because many species migrate vertically, preferring deep water during the day.

11. Most, if not all, adult fish will tend to avoid the thermal plume during the summer and many species will be attracted during the winter, including undesirable forms such as rays and sharks. Additionally, many species of fish may be attracted to the water currents induced, or attracted to the underwater structure, as observed in artificial reef construction.

12. Power plant shutdown during the winter will not result in severe cold shock to fish acclimated to plume temperatures at any of the sites.

13. Because of the small volume of water affected, inshore-offshore and northward-southward fish migrations will not be affected. Fish at sea apparently spawn over large geographical areas, a desirable characteristic which will help avoid depletion of this relatively slow reproducing group.

14. If intake structures are not properly designed, the attractiveness of the plant to fish generally and excessive water velocities at the

intake could result in impingement of fish on intake screens and their subsequent death. The design information required to avoid this exists, however.

16. Adult benthic animals will not be exposed to the thermal plume because it is buoyant and moves away from the bottom. If unusual current conditions were to force the plume to the bottom, sexually mature benthic animals actually exposed to the plume might conceivably be induced to spawn out of season. Diversity indices of benthic animals will remain unchanged.

17. Higher plants and attached algae will not be affected by the thermal plume as they will not occur at the water depth being considered.

18. Fouling will occur unless the structure is suitably protected with antifouling paints. Fouling groups such as hydroids, bryozoa, and calcareous tubeworms will predominate. If allowed to occur, the fouling community that develops may attract mobile species such as fish.

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Section 7

RADIONUCLIDE DISTRIBUTION IN THE SEA

The purpose of releasing low-level radioactive waste to the sea during normal operation is to reduce the radionuclide concentration greatly below permissible levels by dilution with large amounts of sea water. The rate of dilution is controlled by the following processes:

1. Motion of the sea water.
2. Radioactive decay.
3. Settling to the bottom.
4. Chemical reactions.
5. Biological uptake and release.

These processes are best understood by describing the natural forces that determine the path of the radionuclides after they are released by the underwater power plant. The intake pipe for the condenser cooling water is near the seabed. The denser bottom sea water is generally more saline as well as cooler than surface water. During normal operation, the liquid radioactive waste is pumped into the condenser cooling water as it passes through the condensers. In our typical plant, the condenser cooling water temperature rises 25°F and is discharged to the sea as a horizontal jet from a 15-ft diameter pipe. Because the discharge water is hotter, it is less dense than the water around it, and the jet curves upward because of its buoyancy (see figures 30 and 31, and section 5 on thermal diffusion analysis). The concentration of each radionuclide in the buoyant jet is reduced by entrainment of the enveloping water. The upward motion of the jet is halted either by the surface or by a thermocline which often prevails in summer.

At either of these levels, the mixed discharge water spreads, and as the inertia of the jet declines, the motion of the sea water becomes the dominant process in mixing. The mixed discharge water cools by mixing with sea water and by losing heat to the atmosphere. When the temperature of the mixed discharge water near the surface drops to within a few degrees Fahrenheit of the sea water around it, the density of the former will equal the density of the latter, since the mixed discharge water will be more saline. When the temperature of the mixed discharge water and the enveloping sea water are the same, the more saline mixed discharge water will be denser, and

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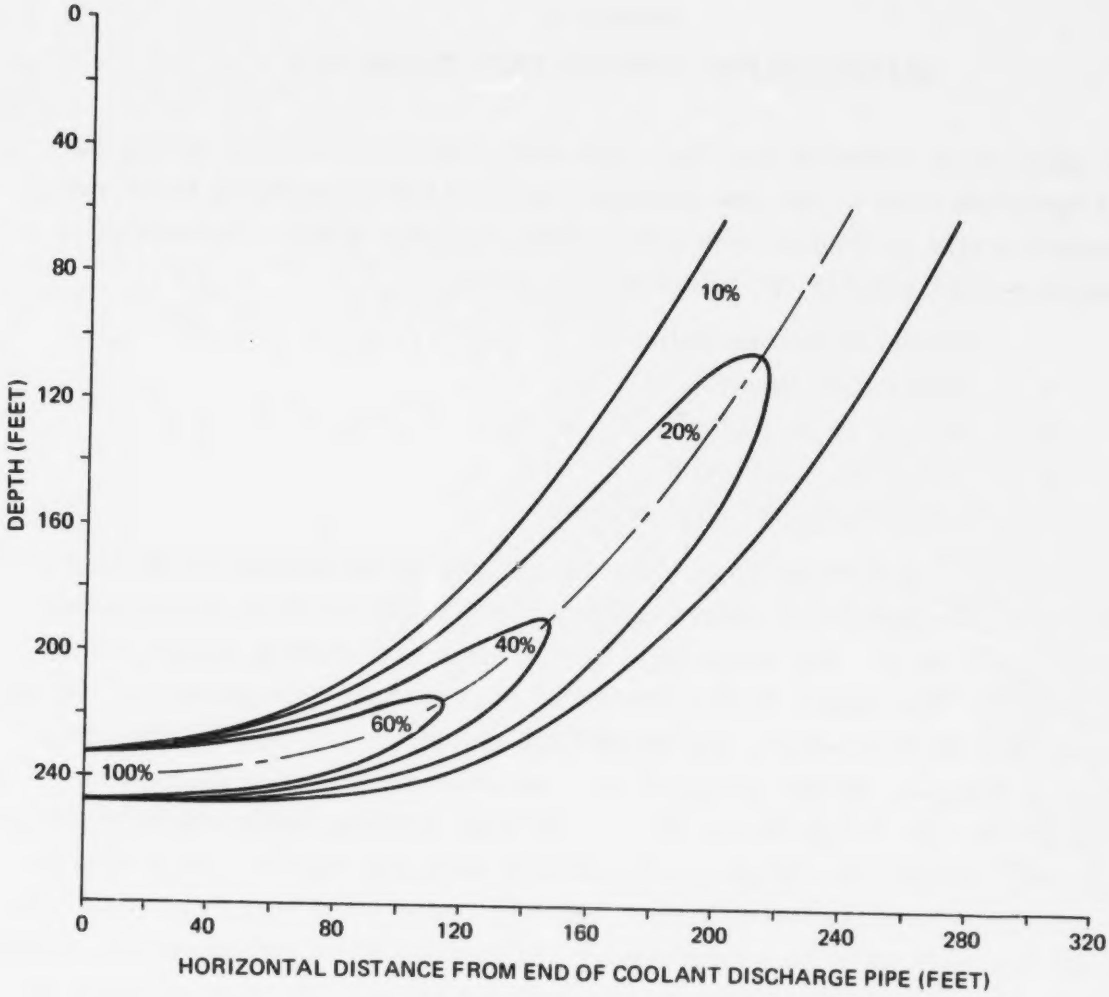


Figure 30. Relative Radionuclide Concentration in the Buoyant Jet in Winter, Normal Operation

it will descend. The descent of the mixed discharge water will contribute to vertical mixing of the radionuclides in the sea.

The chemical form of each radionuclide may or may not be the same as that of the naturally occurring element. If the chemical form is the same, it will be indistinguishable, for any chemical process in the sea, from the naturally occurring element. If the chemical form is different, uptake of the radionuclide by marine biota may differ from uptake of the naturally occurring element. The radionuclide may change to the chemical form of the naturally occurring element, or may adsorb to particular matter, either organic or

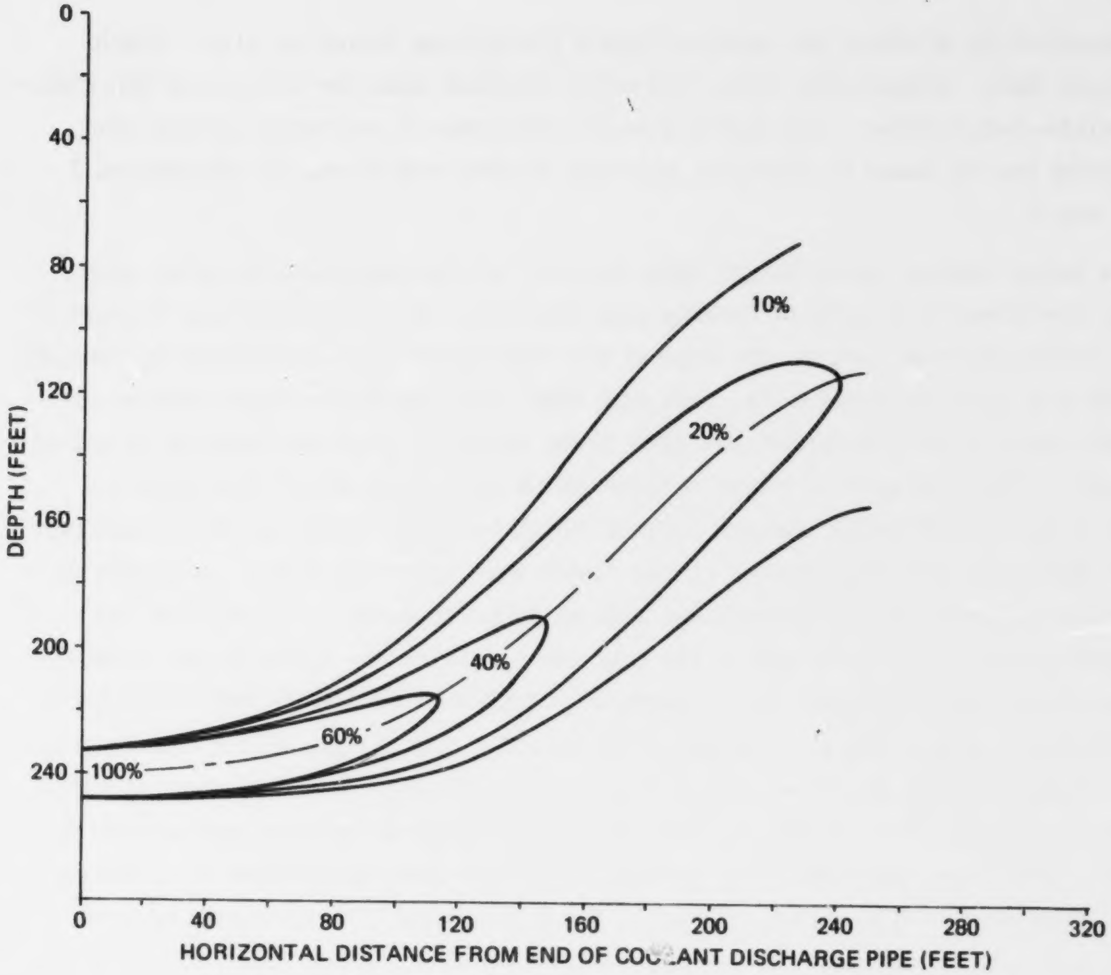


Figure 31. Relative Radionuclide Concentration in the Buoyant Jet in Summer, Normal Operation

silt, and may settle to the bottom. Evidence of changes in the physical or chemical form of radionuclides have been observed at the mouth of the Columbia River in Washington. These radionuclides, originating at the Hanford reactors many miles upstream, are deposited in greater quantities on the bottom at the mouth of the river than either upstream or farther out to sea.

The course of the radionuclide-laden water, after it comes to the end of the jet, is determined primarily by the sea water motion in the neighborhood of the site. Such motion may vary in size from several hundred miles to molecular size. The effects of these sea water motions are complex and best described by dividing the motions into three groups based on size: much larger than, comparable with, and much smaller than the volume of the radionuclide-laden water. Examples and descriptions of sea water motion and mixing can be found in previous sections of this report and in references 1, 2, and 3.

Sea water motion much larger than the size of the radionuclide-laden water has the effect of a current flowing past the site. This current may be part of an ocean current such as the edge of the Gulf Stream off southeastern Florida, part of a gyre or large eddy, part of a tidal flow, part of a wind-driven current, part of the characteristic flow in an estuary, or a combination of all of these. The presence of some current at all times and at all four sites is assured by drift bottle measurements which indicate continual flow, although the direction and magnitude of these flows may vary with time. A plume of higher radionuclide concentration will be detected down current from the power plant. If the current at the site were uniform in strength and direction, this down-current plume for continuously released radionuclides would be symmetric, and a line of constant concentration would resemble a teardrop in the down-current direction (see figures 32 and 33). Radionuclide concentration would decrease with distance from the site because of mixing and natural decay. However, currents past the site are often uniform neither in direction nor magnitude. The direction may change with time or with distance from the site. In either case, the change should be slow, since these currents are caused by relatively large ocean movements. The velocity across the current may vary, such as decreasing from the surface to the bottom or as one approaches the shore. If such a velocity gradient exists, the downstream plume will be distorted, but not greatly: the shearing or elongation of the plume will usually occur in the direction of the current. At longer distances from the site, any regularity or symmetry in the shape of the downstream plume will eventually be lost to shore, island, or bottom boundary effects; or to irregular eddies or spurs from adjoining currents.

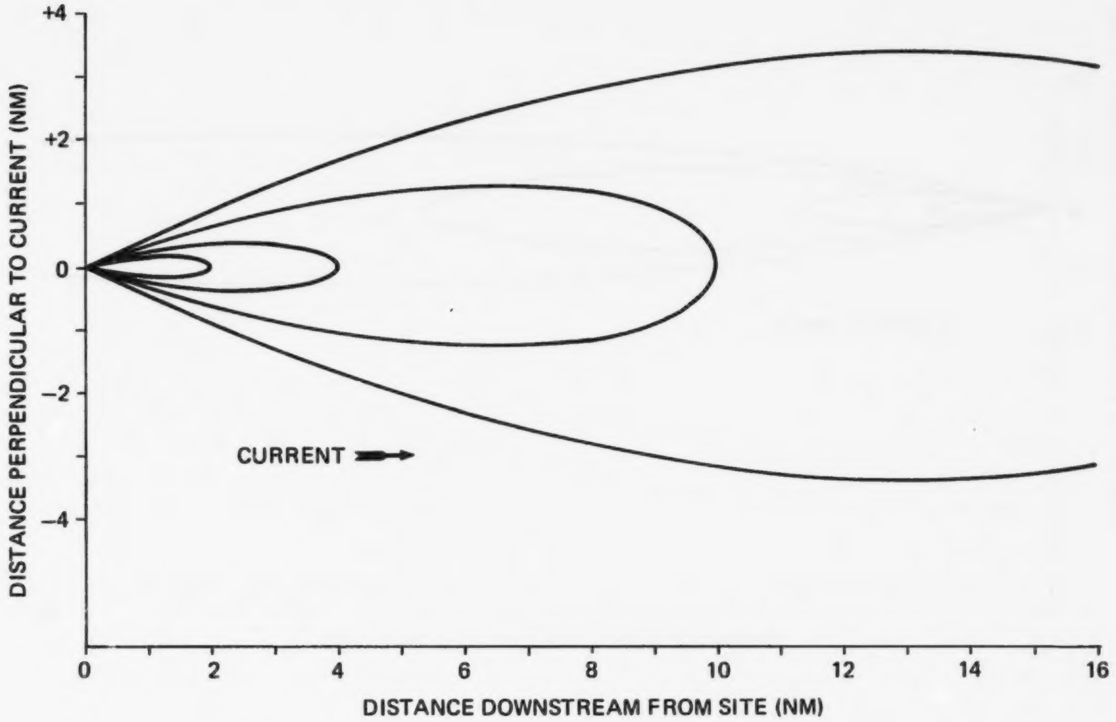


Figure 32. Isoconcentration Lines in the Down-current Plume for Radionuclides Having One-day Half-lives

Sea water motion comparable in size with the downstream plume causes the greatest irregularity in radionuclide concentrations. Eddies of comparable size, changing tides, or winds perpendicular to large current flows will cause irregular or difficult-to-predict radionuclide distributions. The surface current may flow in one direction while the bottom current flows in the opposite, as is typical in estuaries. This might occur at the Sea Girt site, which is in the Hudson River Channel.

Sea water motion much smaller than the size of the downstream plume will usually consist of small eddies. These small eddies are the major cause of mixing or diffusion of radionuclides with surrounding sea water. Radionu-

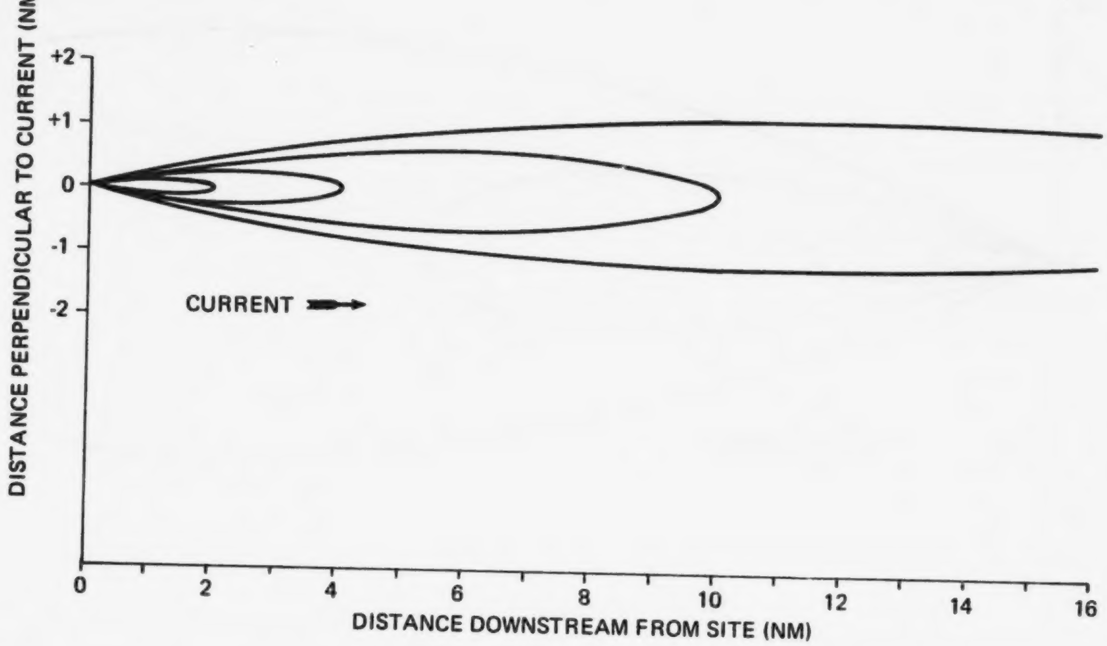


Figure 33. Isoconcentration Lines in the Down-current Plume for Radionuclides Having Half-lives Greater than 100 Days

clide diffusion caused by molecular motion is inconsequential when compared with small eddy diffusion. Experimental measurements on dye releases indicate that dye diffusion is proportional to distance downstream from the site, regardless of current velocity (pages 91 through 120, reference 1).

Beyond the effective range of the downstream plume, a natural barrier may confine the radionuclide-laden sea water and allow only partial mixing with the open ocean. This condition exists in the Gulf of Maine where Georges Bank and Browns Bank partially confine the sea water in the Gulf, and mixing within the Gulf is dominated by a large gyre that is present for most of the year. Part of the radionuclides released from the power plant are carried to the open ocean, while part are recirculated past the site, increasing the radionuclide concentration in the recirculating volume. The average radionuclide concentration will reach an equilibrium that depends on the release rate from the power plant, the loss rate from natural radioactive decay, and the percentage that mixes with the open ocean. The radionuclide concentration within the recirculating volume will vary with location, depending on the current pattern and on time elapsed after release as related to natural radioactive decay.

As mentioned in the previous paragraphs, natural radioactive decay substantially reduces radionuclide concentration: the shorter the half-life, the greater the reduction. Exceptions are radionuclides having long half-lives such as cesium-137, 30.0 yr; strontium-90, 27.7 yr; and tritium, 12.26 yr. The usual result of natural decay is a stable isotope which presents no potential hazard,but some radionuclides decay to a second radionuclide, which in turn may decay to a third radionuclide before decaying to a stable isotope. These decay chains of two or three radionuclides, which are also being released directly from the power plant, complicate prediction of the radionuclide distribution in the sea.

Mixing can also occur through biological uptake of radionuclides by pelagic marine organisms in regions of high radionuclide concentration, followed by release of these radionuclides by the same organisms in regions of low radionuclide concentration. Little is known about mixing by biological uptake and release, and it would be difficult to predict radionuclide concentrations from this type of mixing. Mixing caused by biological uptake and release is small in comparison with mixing from the motion of sea water, and is not studied in this report.

METHOD OF ANALYSIS

Release of radionuclides is assumed to occur continuously during normal operation. This assumption is discussed in the section on release of radionuclides and in the section on effect of radionuclides on man and marine biota.

No information was available from the reactor manufacturer about the chemical form of the radionuclides on release. Chemical activity and the food web are intimately related, and are analyzed together under effect on man and marine biota, p 181. The effect of chemical reactions on radionuclide distribution in the sea is not studied in this report, but the biological effects are discussed below under effect on man and marine biota. The settling of radionuclides to the bottom is not studied in detail. The omission of deposition in the calculation of radionuclide concentration in the sea water is a cautious assumption, since a loss term is omitted which results in a higher radionuclide concentration in the sea water than would actually occur. The effects of radionuclides settling to the bottom on man and marine biota are considered below. The effects of sea water motion and radioactive decay on radionuclide distribution in the sea are analyzed concurrently.

Because of the extremely complex interrelations among patterns of sea water motion, only the more regular motions can be easily analyzed. For this analysis, sea water motion is divided into:

1. The buoyant jet.
2. The downstream plume.
3. The recirculating volume.

Simplifying assumptions are made for each type of motion, and radionuclide concentrations in sea water are calculated beginning at the highest concentration at the end of the discharge pipe, and progressing to lower concentrations in greater volumes of sea water at greater distances from the site. This data is believed necessary by the following reasoning. Any effect of radionuclides released from a submerged plant on man, must begin with uptake of radionuclides by marine organisms. If the average radionuclide concentration in a volume of water that is the natural habitat of these marine organisms is known, sufficient information is available to begin calculating the amount of each radionuclide carried to man via the food web. Radionuclide concentrations are required for a range of sea water volumes, since natural habitats range from the small habitat of shellfish to the large habitat of typical sportfish.

RADIONUCLIDE CONCENTRATION IN THE BUOYANT JET

The buoyant jet is defined as the jet of condenser cooling water discharged horizontally at an elevated temperature by the power plant. The shape of this jet as it turns upward depends on the diameter of the discharge nozzle, on the exit velocity of the coolant, on the density difference between the jet water and enveloping water, and on the velocity and direction of the sea water flowing past the power plant. The density difference between the jet water and the enveloping water depends on the corresponding temperature and salinity differences. All of these quantities vary with time and location except for the nozzle diameter (15 feet) and the maximum coolant exit velocity (7.67 fps). To calculate radionuclide concentrations in the jet at all four sites and for all naturally occurring combinations of these variables, would produce a plethora of data with but small variations in concentration and jet volume among them.

In this study a buoyant jet is analyzed for a single site and for average sea conditions, and is assumed to provide sufficient data for evaluation of the effect of radionuclides on man and marine biota. The site chosen is that off Miami, Florida. Radionuclide concentrations and corresponding volumes of water are calculated in the Miami jet for average temperature and salinity depth profiles in both summer and winter for zero current past the site, and for zero radionuclide concentration at the intake. Summer and winter conditions are separately calculated, since a thermocline often exists during a summer day, forming a barrier to the upward motion of the thermal plume. The assumptions of zero current and zero radionuclide intake simplify the analysis, but are academic since neither are true in the natural state, and it is difficult to imagine their coexistence. Drift bottle data prove that some current always exists at each site, and this current would transport the radionuclides away from the site. This current will displace the jet but not greatly distort it, so the zero current assumption will give valid results. Since sea water recirculates past the power plant at some sites, radionuclides will reenter the condenser cooling channel. These reentering radionuclide concentrations are expected to be less than 1 percent of the discharge concentrations (radionuclide recirculation is discussed further, below). Consequently, the assumption of zero intake is valid for practical analysis. Finally, natural radioactive decay is not included in the calculation of radionuclide concentrations in the jet, since time spent (about 2 min) in the jet is short relative to the radionuclide half-lives.

Theory

Entrainment of enveloping sea water is the process that reduces radionuclide concentration or temperature in the buoyant jet. Consequently, the same mathematical theory is used to calculate the radionuclide concentrations or temperature in the jet. Consult the section on thermal diffusion analysis for theory on this process.

Results

Isoconcentration lines are calculated for 60, 40, 20, and 10 percent of the maximum radionuclide concentration at the discharge nozzle. These isoconcentration lines show the shapes of the buoyant jets in summer and winter in figures 30 and 31 for the maximum coolant discharge rate of 600,000 gpm. The radionuclide concentrations and specific activities at the end of the discharge pipe and for 60, 40, 20, and 10 percent of discharge concentration are given in table 19. The concept of radionuclide specific activity is described below under effect on man and marine life. Volumes of water within the isoconcentration surfaces, of which figures 30 and 31 are two-dimensional section views, are also given in table 19.

RADIONUCLIDE CONCENTRATION IN THE DOWNSTREAM PLUME

The existence of a downstream plume is certain, yet under the influence of changing wind, tide, and currents the plume will meander, change direction, and be asymmetric. Mathematical models expressed as differential equations have been formulated to predict the three-dimensional time-dependent distribution of radionuclides in the downstream plume (see reference 1). These differential equations are either impossible or very difficult to solve in the present state of the art. They also require oceanographic data which is not available in the literature. In addition, some simplifying assumptions have to be made which reduce the effectiveness of these complex models in predicting actual radionuclide concentrations; e.g., in some models natural radioactive decay is omitted.

If conservative assumptions are allowed, a simpler mathematical model can be formulated in keeping with the purpose of this study, which is to evaluate the effects of radionuclides on man and marine life and not to predict the de-

Table 19. Radionuclide Concentrations in the Buoyant Jet, Normal Operation

Conc. = concentration, μCi/cc
Sp Act. = specific activity, μCi/gm
( ) = power of ten

	Max Permissible		Discharge		60%		40%		20%		10%	
Nuclide	Conc.	Sp Act.	Conc.	Sp Act.	Conc.	Sp Act.	Conc.	Sp Act.	Conc.	Sp Act.	Conc.	Sp Act.
H-3	4.7(-2)	1.4(-3)	5.23(-6)	4.84(-5)	3.15(-6)	2.91(-5)	2.10(-6)	1.94(-5)	1.05(-6)	9.68(-6)	5.23(-7)	4.84(-6)
Cr-51	5.0(-7)	3.1(5)	1.68(-10)	3.36(0)	1.01(-10)	2.01(0)	6.72(-11)	1.34(0)	3.36(-11)	6.72(-1)	1.68(-11)	3.36(-1)
Mn-54	3.8(-9)	5.8(2)	1.21(-12)	6.05(-4)	7.26(-13)	3.63(-4)	4.84(-13)	2.42(-4)	2.42(-13)	1.21(-4)	1.21(-13)	6.05(-5)
Fe-55	2.5(-8)	3.9(0)	5.80(-12)	5.80(-4)	3.48(-12)	3.48(-4)	2.32(-12)	2.32(-4)	1.16(-12)	1.16(-4)	5.80(-13)	5.80(-5)
Co-58	2.3(-8)	8.9(1)	2.05(-10)	4.10(-1)	1.23(-10)	2.46(-1)	8.20(-11)	1.64(-1)	4.10(-11)	8.20(-2)	2.05(-11)	4.10(-2)
Fe-59	4.7(-9)	8.9(-1)	9.39(-13)	9.39(-5)	5.64(-13)	5.64(-5)	3.76(-13)	3.76(-5)	1.88(-13)	1.88(-5)	9.39(-14)	9.39(-6)
Co-60	1.5(-8)	3.3(1)	2.30(-11)	4.60(-2)	1.38(-11)	2.76(-2)	9.20(-12)	1.84(-2)	4.60(-12)	9.20(-3)	2.30(-12)	4.60(-3)
Ge-78	--	--	9.50(-16)	1.36(-5)	5.70(-16)	8.16(-6)	3.80(-16)	5.44(-6)	1.90(-16)	2.72(-6)	9.50(-17)	1.36(-6)
As-78	--	--	1.85(-15)	6.17(-7)	1.11(-15)	3.69(-7)	7.40(-16)	2.46(-7)	3.70(-16)	1.23(-7)	1.85(-16)	6.17(-8)
Br-84	--	--	2.90(-11)	4.46(-7)	1.74(-11)	2.67(-7)	1.16(-11)	1.78(-7)	5.80(-12)	8.92(-8)	2.90(-12)	4.46(-8)
Rb-88	--	--	1.59(-9)	1.33(-2)	9.54(-10)	7.98(-3)	6.36(-10)	5.32(-3)	3.18(-10)	2.66(-3)	1.59(-10)	1.33(-3)
Rb-89	--	--	3.95(-11)	3.29(-4)	2.37(-11)	1.98(-4)	1.58(-11)	1.32(-4)	7.90(-12)	6.58(-5)	3.95(-12)	3.29(-5)
Sr-89	7.9(-6)	1.1(3)	4.04(-11)	5.05(-6)	2.43(-11)	3.03(-6)	1.62(-11)	2.02(-6)	8.08(-12)	1.01(-6)	4.04(-12)	5.05(-7)
Sr-90	7.9(-8)	4.2(0)	1.91(-13)	2.39(-8)	1.15(-13)	1.43(-8)	7.64(-14)	9.56(-9)	3.82(-14)	4.78(-9)	1.91(-14)	2.39(-9)
Y-90	3.8(-7)	3.0(4)	5.54(-12)	1.85(-2)	3.33(-12)	1.11(-2)	2.22(-12)	7.40(-3)	1.11(-12)	3.70(-3)	5.54(-13)	1.85(-3)
Sr-91	4.0(-5)	7.8(4)	2.40(-12)	3.00(-7)	1.44(-12)	1.80(-7)	9.60(-13)	1.20(-7)	4.80(-13)	6.00(-8)	2.40(-13)	3.00(-8)
Y-91	5.7(-7)	2.3(3)	1.42(-9)	4.73(0)	8.52(-10)	2.84(0)	5.68(-10)	1.89(0)	2.84(-10)	9.46(-1)	1.42(-10)	4.73(-1)
Y-93	5.7(-7)	1.3(5)	1.84(-11)	6.13(-2)	1.10(-11)	3.69(-2)	7.36(-12)	2.46(-2)	3.68(-12)	1.23(-2)	1.84(-12)	6.13(-3)
Zr-95	9.5(-7)	1.0(3)	4.12(-14)	1.87(-3)	2.47(-14)	1.12(-3)	1.65(-14)	7.48(-4)	8.24(-15)	3.74(-4)	4.12(-15)	1.84(-4)
Nb-95	9.5(-7)	1.8(3)	4.53(-12)	4.53(-1)	2.72(-12)	2.72(-1)	1.81(-12)	1.81(-1)	9.06(-13)	9.06(-2)	4.53(-13)	4.53(-2)
Zr-97	3.2(-7)	1.8(4)	1.90(-12)	8.64(-2)	1.14(-12)	5.19(-2)	7.60(-13)	3.46(-2)	3.80(-13)	1.73(-2)	1.90(-13)	8.64(-3)
Mo-99	7.5(-7)	2.7(3)	1.17(-8)	1.17(0)	7.02(-9)	7.02(-1)	4.68(-9)	4.68(-1)	2.34(-9)	2.34(-1)	1.17(-9)	1.17(-1)
Ru-103	1.3(-6)	--	3.31(-12)	--	1.98(-12)	--	1.32(-12)	--	6.62(-13)	--	3.31(-13)	--
Rh-105	1.9(-6)	--	4.65(-13)	--	2.79(-13)	--	1.86(-13)	--	9.30(-14)	--	4.65(-14)	--
Ru-106	1.6(-7)	--	1.91(-13)	--	1.15(-13)	--	7.64(-14)	--	3.82(-14)	--	1.91(-14)	--

Table 19 (Continued)

	Max Permissible		Discharge		60%		40%		20%		10%	
Nuclide	Conc.	Sp Act.	Conc.	Sp Act.	Conc.	Sp Act.	Conc.	Sp Act.	Conc.	Sp Act.	Conc.	Sp Act.
Pd-109	1.3(-6)	--	9.10(-15)	--	5.46(-15)	--	3.64(-15)	--	1.82(-15)	--	9.10(-16)	--
Ag-111	1.5(-8)	1.3(0)	1.24(-14)	4.13(-5)	7.44(-15)	2.48(-5)	4.96(-15)	1.65(-5)	2.48(-15)	8.26(-6)	1.24(-15)	4.36(-6)
Cd-115	5.7(-9)	7.1(2)	1.77(-15)	1.61(-5)	1.06(-15)	9.66(-6)	7.08(-16)	6.44(-6)	3.54(-16)	3.22(-6)	1.77(-16)	1.16(-6)
Sn-119m	--	--	7.90(-15)	2.63(-6)	4.74(-15)	1.58(-6)	3.16(-15)	1.05(-6)	1.58(-15)	5.26(-7)	7.90(-16)	2.63(-7)
Sn-121	--	--	3.88(-15)	1.29(-6)	2.33(-15)	7.74(-7)	1.55(-15)	5.16(-7)	7.76(-16)	2.58(-7)	3.88(-16)	1.29(-7)
Sn-123	--	--	3.35(-16)	1.12(-7)	2.01(-16)	6.72(-8)	1.34(-16)	4.48(-8)	6.70(-17)	2.24(-8)	3.35(-17)	1.12(-8)
Sn-125	3.2(-5)	3.1(2)	2.54(-17)	8.47(-9)	1.53(-17)	5.07(-9)	1.02(-17)	3.38(-9)	5.08(-18)	1.69(-9)	2.54(-18)	8.47(-10)
Sb-125	1.6(-7)	7.0(1)	5.48(-15)	1.10(-5)	3.30(-15)	6.60(-6)	2.20(-15)	4.40(-6)	1.10(-15)	2.20(-6)	5.48(-16)	1.10(-6)
Te-125m	1.6(-6)	7.0(-1)	3.66(-13)	--	2.19(-13)	--	1.46(-13)	--	7.32(-14)	--	3.66(-14)	--
Sb-126	--	--	6.76(-16)	1.35(-6)	4.05(-16)	8.10(-7)	2.70(-16)	5.40(-7)	1.35(-16)	2.70(-7)	6.76(-17)	1.35(-7)
Sb-127	--	--	8.25(-14)	1.65(-4)	4.85(-14)	9.90(-5)	3.20(-14)	6.60(-5)	1.65(-14)	3.30(-5)	8.25(-15)	1.65(-5)
Te-127m	9.5(-7)	3.5(-1)	1.49(-12)	--	8.94(-13)	--	5.96(-13)	--	2.98(-13)	--	1.49(-13)	--
Te-127	3.2(-6)	2.3(1)	4.95(-12)	--	2.97(-12)	--	1.98(-12)	--	9.90(-13)	--	4.95(-13)	--
Te-129m	3.2(-7)	1.8(-1)	2.45(-11)	--	1.47(-11)	--	9.80(-12)	--	4.90(-12)	--	2.45(-12)	--
Te-129	1.3(-5)	6.9(1)	1.91(-11)	--	1.15(-11)	--	7.64(-12)	--	3.82(-12)	--	1.91(-12)	--
I-129	6.3(-10)	7.5(0)	5.43(-17)	9.05(-10)	3.27(-17)	5.43(-10)	2.18(-17)	3.62(-10)	1.09(-17)	1.81(-10)	5.43(-18)	9.05(-11)
Te-131m	6.3(-7)	2.2(0)	1.89(-11)	--	1.13(-11)	--	7.56(-12)	--	3.78(-12)	--	1.89(-12)	--
I-131	3.2(-9)	3.2(1)	3.13(-9)	5.22(-2)	1.88(-9)	3.12(-2)	1.25(-9)	2.08(-2)	6.26(-10)	1.04(-2)	3.13(-10)	5.22(-3)
Te-132	3.2(-7)	7.3(-1)	2.49(-10)	--	1.49(-10)	--	9.96(-11)	--	4.98(-11)	--	2.49(-11)	--
I-132	--	1.1(3)	7.35(-10)	1.23(-2)	4.41(-10)	7.38(-3)	2.94(-10)	4.92(-3)	1.47(-10)	2.46(-3)	7.35(-11)	1.23(-3)
I-133	1.1(-8)	1.2(2)	4.03(-9)	6.72(-2)	2.42(-9)	4.02(-2)	1.61(-9)	2.68(-2)	8.06(-10)	1.34(-2)	4.03(-10)	6.72(-3)
Te-134	--	--	1.63(-11)	--	9.78(-12)	--	6.52(-12)	--	3.26(-12)	--	1.63(-12)	--
I-134	1.6(-7)	1.9(3)	3.87(-10)	6.45(-3)	2.32(-10)	3.87(-3)	1.55(-10)	2.58(-3)	7.74(-11)	1.29(-3)	3.87(-11)	6.45(-4)
Cs-134	9.0(-7)	1.5(-2)	2.74(-8)	7.20(-5)	1.65(-8)	4.32(-5)	1.10(-8)	2.88(-5)	5.48(-9)	1.44(-5)	2.74(-9)	7.20(-6)
I-135	3.2(-8)	3.7(2)	1.79(-9)	2.98(-2)	1.07(-10)	7.15(-3)	7.16(-10)	1.19(-3)	3.58(-10)	5.96(-3)	1.79(-10)	2.98(-3)

Table 19 (Continued)

	Max Permissible		Discharge		60%		40%		20%		10%	
Nuclide	Conc.	Sp Act.	Conc.	Sp Act.	Conc.	Sp Act.	Conc.	Sp Act.	Conc.	Sp Act.	Conc.	Sp Act.
Cs-136	6.0(-6)	1.4(-1)	7.97(-10)	2.10(-6)	4.77(-10)	1.26(-6)	3.18(-10)	8.40(-7)	1.59(-10)	4.20(-7)	7.97(-11)	2.10(-7)
Cs-137	2.0(-6)	2.1(-2)	1.00(-7)	2.73(-4)	6.00(-8)	1.64(-4)	4.00(-8)	1.09(-4)	2.00(-8)	5.46(-5)	1.00(-8)	2.73(-5)
Cs-138	--	--	3.56(-9)	9.36(-6)	2.13(-9)	5.61(-6)	1.42(-9)	3.74(-6)	7.12(-10)	1.87(-6)	3.56(-10)	9.36(-7)
Ba-140	3.2(-6)	1.5(2)	4.84(-12)	1.61(-4)	2.91(-12)	9.66(-5)	1.94(-12)	6.44(-5)	9.68(-13)	3.22(-5)	4.84(-13)	1.61(-5)
La-140	3.8(-7)	4.8(3)	4.70(-12)	1.57(-2)	2.72(-12)	9.42(-3)	1.88(-12)	6.28(-3)	9.40(-13)	3.14(-3)	4.70(-13)	1.57(-3)
Ce-141	1.7(-6)	1.2(3)	4.35(-12)	1.45(-2)	2.51(-12)	8.70(-3)	1.64(-12)	5.80(-3)	8.70(-13)	2.90(-3)	4.35(-13)	1.45(-3)
Ce-143	7.6(-7)	6.8(3)	4.16(-12)	1.39(-2)	2.49(-12)	8.34(-3)	1.66(-12)	5.56(-3)	8.32(-13)	2.78(-3)	4.16(-13)	1.39(-3)
Pr-143	9.5(-8)	1.8(3)	4.27(-12)	1.42(-2)	2.56(-12)	8.52(-3)	1.71(-12)	5.68(-3)	8.54(-13)	2.84(-3)	4.27(-13)	1.42(-3)
Ce-144	1.9(-7)	2.3(1)	2.95(-12)	9.83(-3)	1.47(-12)	5.91(-3)	9.80(-13)	3.94(-3)	4.90(-13)	1.97(-3)	2.95(-13)	9.83(-4)
Pr-145	--	--	6.35(-13)	2.12(-3)	3.81(-13)	1.27(-3)	2.54(-13)	8.48(-4)	1.27(-13)	4.24(-4)	6.35(-14)	2.12(-4)
Nd-147	1.1(-7)	1.9(3)	1.48(-12)	4.93(-3)	8.88(-13)	2.96(-3)	5.92(-13)	1.97(-3)	2.96(-13)	9.86(-4)	1.48(-13)	4.93(-4)
Pm-147	3.8(-7)	1.6(2)	5.85(-13)	1.95(-3)	3.51(-13)	1.17(-3)	2.34(-13)	7.80(-4)	1.17(-13)	3.90(-4)	5.85(-14)	1.95(-4)
Pm-149	7.6(-8)	9.5(3)	5.62(-13)	1.87(-3)	3.36(-13)	1.12(-3)	2.24(-13)	7.48(-4)	1.12(-13)	3.74(-4)	5.62(-14)	1.87(-4)
Pm-151	--	--	1.75(-13)	5.83(-4)	1.05(-13)	3.51(-4)	7.00(-14)	2.34(-4)	3.50(-14)	1.17(-4)	1.75(-14)	5.83(-5)
Sm-151	5.0(-7)	1.6(2)	4.30(-15)	1.43(-5)	2.58(-15)	8.58(-6)	1.72(-15)	5.72(-6)	8.60(-16)	2.86(-6)	4.30(-16)	1.43(-6)
Sm-153	1.5(-7)	1.6(4)	1.05(-13)	3.50(-4)	6.30(-14)	2.10(-4)	4.20(-14)	1.40(-4)	2.10(-14)	7.00(-5)	1.05(-14)	3.50(-5)
Eu-155	3.8(-7)	2.7(2)	6.23(-15)	2.08(-5)	3.75(-15)	1.25(-5)	2.50(-15)	8.32(-6)	1.25(-15)	4.16(-6)	6.23(-16)	2.08(-6)
Eu-156	--	--	9.30(-15)	3.10(-5)	5.58(-15)	1.55(-5)	3.72(-15)	9.30(-6)	1.86(-15)	6.20(-6)	9.30(-16)	3.10(-6)
Eu-157	--	--	2.01(-15)	6.70(-6)	1.21(-15)	4.02(-6)	8.04(-16)	2.68(-6)	4.02(-16)	1.34(-6)	2.01(-16)	6.70(-7)
Gd-159	1.5(-7)	2.4(4)	3.56(-16)	1.19(-6)	2.13(-16)	7.14(-7)	1.42(-16)	4.76(-7)	7.12(-17)	2.38(-7)	3.56(-17)	1.19(-7)
Total Activity			1.57(-7)									
Volume of Water (cc)					17,000		43,000		220,000		380,000*	

*Only the volume to the open end of the 10% isoconcentration line of figures 30 and 31.

tailed motion of ocean currents. Such assumptions result in a higher calculated radionuclide concentration than actually would occur. First, we may ignore the effects of eddies and currents comparable in size with the downstream plume. Secondly, we assume that the current past the site is uniform in strength and direction, so that there is no shearing of the downstream plume. These assumptions compound the conservatism, since both omit effects contributing to greater mixing. It is further assumed that good vertical mixing occurs at the site from action of the buoyant jet and thermal convection. Dye release experiments have shown that there is much less vertical than horizontal mixing in ocean currents. For this study, no vertical mixing is assumed to occur past one nautical mile down-current from the site; i.e., beyond the effective limit of the buoyant jet. The model chosen for continuous release from a fixed source is the "spreading disk" model recommended by Okubo and Pritchard (1969) and by Ito, Fukuda, and Tanigawa (1966). The model is described under Theory, below.

The release rate of radionuclides used for the downstream plume calculation is the annual discharge given in table 2, p 29.

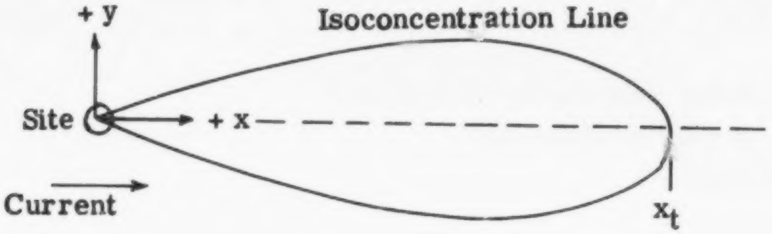
The current velocities used in the calcuation are from the site data as follows:

	Velocity (nm/day)	
Site	Maximum	Minimum
Wiscasset, Me.	9.72	0.54
Sea Girt, N.J.	11.00	2.00
Miami, Fla.	24.00	6.00
San Onofre, Cal.	16.80	--
All sites	24.00	0.50

Radionuclide concentrations are not calculated beyond 40 nm down current from the site because the accuracy of the mathematical model becomes limited with distance.

Theory

The following sketch shows an isoconcentration line in the downstream plume where the plux x-coordinate is down current, the y-coordinate is perpendicular to the current, and the origin is at the site.



The following derivation initially assumes negligible radioactive decay (half-life > 100 days), and assumes constant concentration with depth. The spreading disk model assumes that the radionuclide distribution perpendicular to the current is a normal distribution:

$$\phi(x, y) = \phi(x, 0)\, e^{-\frac{y^2}{2\sigma_y^2}}$$

where:

$\phi(x,y)$ = radionuclide concentration (μ Ci/cc) at location x, y
$\phi(x,0)$ = radionuclide concentration (μ Ci/cc) on the centerline
σ_y = standard deviation in (nm) y-direction

Assume the standard deviation in the y-direction proportional to the downstream distance, x:

$$\sigma_y^2 = c^2 x^2$$

where c is a constant.

Substituting:

$$\phi(x,y) = \phi(x,0)\, e^{-\frac{y^2}{2c^2x^2}}$$

This empirical formula provides a good fit to experimental data on dye releases in the sea, and for the best fit c = 0.1 (page 477, reference 3).

To evaluate $\phi(x,0)$, let

Q = radionuclide release rate at the site (curies/year)

By conservation of radionuclides:

$$Q dt = D U_o dt \int_{-\infty}^{+\infty} \phi(x,0)\ e^{-\frac{y^2}{2c^2x^2}}\ dy$$

where:

D = depth of water (assumed constant)(nm)

U_o = velocity of current (nm/day)

dt = time interval

Integrating:

$$Q dt = 2 D U_o\ \phi(x,0)\ dt \int_{o}^{\infty} e^{-\frac{y^2}{2c^2x^2}}\ dy$$

$$Q dt = 2 D U_o\ \phi(x,0)\ dt\ \frac{\sqrt{\pi}}{2}\sqrt{2}\ \ cx$$

$$\phi(x,0) = \frac{Q}{\sqrt{2\pi}\ D U_o c x}$$

Substituting:

$$\phi(x,y) = \frac{Q}{\sqrt{2\pi}\ D U_o\ c x}\ e^{-\frac{y^2}{2c^2x^2}}$$

This basic equation must be modified to include radioactive decay for decay chains of up to three radionuclides. The following formulas for the i^{th} radionuclide concentration in the decay chain are derived in appendix C:

$$\phi_i(x,y) = \frac{f_i(x)}{\sqrt{2\pi}\ D U_o c x}\ e^{-\frac{y^2}{2c^2x^2}}$$

where $f_i(x) = Q_1 e^{-\frac{\lambda_1 x}{U_o}}$

for the first of a 1, 2, or 3 radionuclide chain, where:

$$f_2(x) = \frac{Q_1 \lambda_2 f_{d2}}{\lambda_2 - \lambda_1} \left(e^{-\frac{\lambda_1 x}{U_o}} - e^{-\frac{\lambda_2 x}{U_o}} \right) + Q_2 e^{-\frac{\lambda_2 x}{U_o}}$$

for the second of a 2 or 3 radionuclide chain, where:

$$\begin{aligned} f_3(x) = {} & \frac{\lambda_3 \lambda_2 Q_1 f_{d2} f_{d3}}{(\lambda_3 - \lambda_2)(\lambda_2 - \lambda_1)} \left(e^{-\frac{\lambda_3 x}{U_o}} - e^{-\frac{\lambda_2 x}{U_o}} \right) \\ & - \frac{\lambda_3 \lambda_2 Q_1 f_{d2} f_{d3}}{(\lambda_3 - \lambda_1)(\lambda_2 - \lambda_1)} \left(e^{-\frac{\lambda_3 x}{U_o}} - e^{-\frac{\lambda_1 x}{U_o}} \right) \\ & + \frac{\lambda_3 Q_1 (1-f_{d2})}{\lambda_3 - \lambda_1} \left(e^{-\frac{\lambda_1 x}{U_o}} - e^{-\frac{\lambda_3 x}{U_o}} \right) \\ & + \frac{\lambda_3 Q_2 f_{d3}}{\lambda_3 - \lambda_2} \left(e^{-\frac{\lambda_2 x}{U_o}} - e^{-\frac{\lambda_3 x}{U_o}} \right) \\ & + Q_3 e^{-\frac{\lambda_3 x}{U_o}} \end{aligned}$$

for the third radionuclide in a chain, where:

λ = decay constant for the i^{th} (day^{-1}) radionuclide = .639/half-life

f_{d2} = decay fraction of first radionuclide to second, $(1-f_{d2})$ decays directly to the third radionuclide

f_{d3} = decay fraction of second radionuclide to the third, $(1-f_{d3})$ decays directly to the stable nuclide.

The formula for the shape of the isoconcentration curve is derived as follows for the i^{th} radionuclide. By definition of the isoconcentration line:

$$\phi_i(x, y_s) = \phi_i(x_t, 0)$$

where x_t = downstream terminal value of x on the isoconcentration curve.

Substituting:

$$\frac{f_i(x)}{\sqrt{2\pi}\ DU_o\ cx}\ e^{-\frac{y_s^2}{2c^2x^2}} = \frac{f_i(x_t)}{\sqrt{2\pi}\ DU_o cx}$$

Solving:

$$y_s^2 = 2c^2x^2 \ln\left(\frac{x_t}{x} \cdot \frac{f_i(x)}{f_i(x_t)}\right)$$

Examples of the shape of the isoconcentration curves in the down-current plume for single radionuclides having half-lives of one day and greater than 100 days are given in figures 32 and 33.

Since isoconcentration curves for all radionuclides would be a formidable task, the maximum width, y_m, of each isoconcentration curve is derived. The derivation is done first for a single radionuclide where decay is insignificant (half-life > 100 days) beginning with the isoconcentration curve:

$$y_s^2 = 2c^2x^2 \ln \frac{x_t}{x}$$

By setting the derivative $\frac{dy}{dx} = 0$,

$$x_m = \frac{x_t}{\sqrt{e}} = .607\, x_t$$

where x_m = distance down current (nm) for maximum y. This formula for x_m is assumed valid for isoconcentration curves with radioactive decay, and can be visually verified from figure 32. This formula for x_m is also assumed valid in this study for the second or third radionuclides in a decay chain.

The formula for the volume of water within an isoconcentration line and over a depth, D, is derived. The definition of the volume, V, is:

$$V = 2D \int_0^{x_t} y_s dx$$

Substitute for y_s for a single radionuclide where decay is insignificant (half-life > 100 days).

$$V = 2\sqrt{2}\ c\ D \int_0^{x_t} \left(\ln \frac{x_t}{x}\right)^{1/2} x dx$$

The evaluation of this integral yields: $\frac{\sqrt{\pi}}{4\sqrt{2}} x_t^2$

Substituting:

$$V = \frac{\sqrt{\pi}}{2}\ c\, D\, x_t^2$$

Evaluate y_m in terms of x_t for a single radionuclide with negligible decay beginning with the formula for y_s:

$$y_m^2 = 2c^2 x_m^2 \ln \frac{x_t}{x_m}$$

Substituting for $x_m = \frac{x_t}{\sqrt{e}}$

$$y_m^2 = \frac{c^2 x_t^2}{e}$$

or

$$c x_t = \sqrt{e}\ y_m$$

Substituting in the volume for one x_t:

$$V = \frac{\sqrt{\pi\ e}}{2}\ D x_t y_m = 1.46\ D x_t y_m$$

This volume formula is assumed valid for isoconcentration curves with radioactive decay, and has been numerically checked against the 10-nm isoconcentration curve volume in figure 32 for a one-day half-life and found to have a 2.2 percent error. This volume formula is assumed valid in this study for isoconcentration curves for the second and third radionuclides in a decay chain.

The final quantity of interest is the average radionuclide concentration in the volume of water within an isoconcentration curve of the down-current plume. The exact formula involves a hopelessly difficult integral for this engineering study. A simple recursion formula is used to approximate the average radionuclide concentration within the n^{th} isoconcentration curve. Knowing the average radionuclide concentration for the $n-1^{th}$ curve:

$$\overline{\phi}_n = \overline{\phi}_{n-1}\frac{V_{n-1}}{V_n} + \frac{\phi_{n-1} + \phi_n}{2}\left(1 - \frac{V_{n-1}}{V_n}\right)$$

where:

$\overline{\phi}_n$ = average radionuclide concentration within the n^{th} isoconcentration curve

ϕ_n = radionuclide concentration at the n^{th} isoconcentration curve.

V_n = volume of water within the n^{th} isoconcentration curve.

The average radionuclide concentration for the first isoconcentration curve, at $x_t = 1$ nm, is assumed equal to the centerline concentration at $x = 0.5$ nm; that is,

$$\overline{\phi}_1\,(1.0) = \phi(0.5, 0)$$

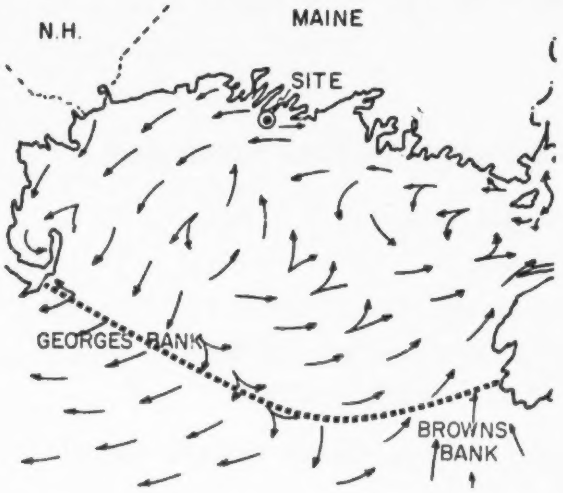
Results

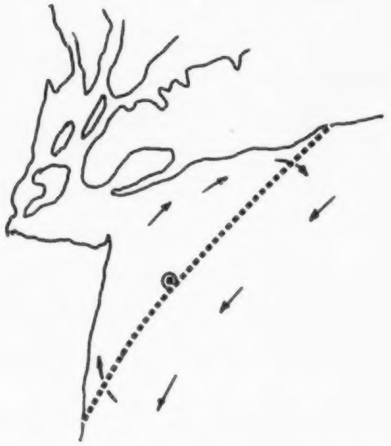
For each of 70 radionuclides, iso- and average concentrations and average specific activities in sea water in the down-current plume are given in appendix D. Data is given for three values of current velocity: 0.5, 4.0, and 24.0 nm/day. Concentrations are highest for the lowest velocity since the least mixing water passes the plant in one day. The depth used is 200 feet = .0329 nm. Concentrations are calculated for 1, 2, 4, 10, 20, and 40 nm down current. The half-width and volume of water for each isoconcentration curve are also calculated.

RADIONUCLIDE CONCENTRATIONS IN THE RECIRCULATING VOLUME

Flow patterns based on drift bottle studies were investigated at each of the four sites, to ascertain whether the site were within a semiconfined body of water in which only partial mixing with the open ocean would occur.

The Wiscasset, Maine site is the only one that definitely has this condition. The boundary is an imaginary line from Nova Scotia to Cape Cod over Browns Bank and Georges Bank (see sketch below, left). A one-box model is used to calculate the average radionuclide concentrations in the Gulf of Maine as described under Theory, below. The data necessary for the calculation are the volume of water in the Gulf of Maine, which was calculated from a Coast and Geodetic Survey chart, and the flow of water leaving the Gulf. The flow rate was calculated from an estimate of the cross sectional flow area from bottom to surface over Georges Bank between Cape Cod and the Gulf of Maine channel, and from the average current velocity for this cross sectional area estimated from surface currents based on drift bottle measurements. Water not escaping to the open ocean recirculates in the large gyre usually present in the Gulf of Maine. The Sea Girt, New Jersey site has a potentially semiconfined volume at certain times of the year. This volume exists in the Hudson River estuary, and is bounded on the north by Long Island and on the west by New Jersey, as shown by the sketch to the right.





This volume may recirculate when aided by a southwest wind. Radionuclide concentration in the recirculating volume was not calculated, since means of estimating the volume of water that escapes to the open ocean are not readily available in the literature. No semiconfined volume exists at the Miami site except for large eddies that move slowly northward over the site. Since these eddies do not remain over the site, no average radionuclide concentrations are calculated for them. Radionuclides released from the power plant would be carried northward along the Florida coast while decaying, mixing with the Gulf Stream in about one week. No evidence of a semiconfined volume exists for the San Onofre, California site. Because of the inconsistencies of ocean currents and the lack of complete data, these box model calculations are only approximate.

Theory

The one-box model is used to calculate radionuclide concentration in equilibrium by equating production and loss terms as described on page 134 of reference 1. The radionuclide concentration is averaged over the semicontained volume or box. By conservation of nuclei for the general case of the i^{th} radionuclide in a decay chain:

$$\begin{array}{ccccccccc} \text{nuclei released} & + & \begin{array}{c}\text{i-1}\\ \text{precursor decay}\end{array} & + & \begin{array}{c}\text{i-2}\\ \text{precursor decay}\end{array} & = & \text{decay loss} & + & \text{dilution loss} \\ \dfrac{Q_i}{\lambda_i} & + & \lambda_{i-1} V \bar{n}_{i-1} f_{d,i} & + & \lambda_{i-2} V \bar{n}_{i-2} (1-f_{d,i-1}) & = & \lambda_i V \bar{n}_i & + & S\bar{n}_i \end{array}$$

where:

Q_i = release rate of the i^{th} radionuclide from the power plant (curies/year)

λ_i = decay constant of i^{th} radionuclide (yr^{-1})

V = volume of water in the box (cc)

$\bar{n}_i$ = atom density of i^{th} isotope in sea (atoms/cc)

S = volume flow rate of water leaving the box (cc/day)

$f_{d,i}$ = decay fraction from $(i-1)^{th}$ to i^{th} radionuclide

Note that appropriate conversion factors must be applied for units to cancel (1 curie = 3.7×10^{10} disintegrations/sec).

Solving for $\bar{n}_i$:

$$\bar{n}_i = \frac{\dfrac{Q_i}{\lambda_i} + \lambda_{i-1} V \bar{n}_{i-1} f_{d,i} + \lambda_{i-2} V \bar{n}_{i-2} (1-f_{d,i-1})}{S + \lambda_i V}$$

Solving for average concentration, $\bar{\phi}_i$:

$$\bar{\phi}_i = \lambda_i \bar{n}_i = \frac{Q_i + \lambda_i V \bar{\phi}_{i-1} f_{d,i} + \lambda_i V \bar{\phi}_{i-2} (1-f_{d,i-1})}{S + \lambda_i V}$$

Results for Wiscasset, Maine Site

The calculated average radionuclide concentrations in the Gulf of Maine are given in table 20. Note that these concentrations become less meaningful for shorter-lived radionuclides, since radioactive decay becomes the predominant loss term and concentration decreases rapidly with distance from the site. Meaningful average concentrations exist for radionuclides having half-lives comparable with or greater than the cycle time of the gyre, which is 100 to 200 days. Since these concentrations are well below permissible levels, the data are not used in this study. These concentrations might be useful if more were known about food webs.

The volume of water in the Gulf of Maine is calculated at 1.6 x 10^{19} cc. The calculated flow of water leaving the Gulf of Maine over the Georges Bank, is an annual average from seasonal estimates based on surface current data, as follows:

Season	Volume Outflow (cc/day x 10^{16})
Spring	2.35
Summer	4.70
Fall	1.61
Winter	2.26
Annual average	2.73

ACCIDENTAL RADIONUCLIDE RELEASE

During a loss-of-coolant accident or a breach-of-containment accident, it is postulated that an amount of radionuclides are unintentionally released to sea (see section 4, radionuclide release), which is conservatively assumed to be larger than the actual amount would be. For either accident the radionuclides are contained in a gaseous mixture of air and steam which is released over a short duration. As the bubbles of gas ascend to the surface, they collapse or disintegrate into finer bubbles, and most radionuclides are absorbed by

Table 20. Average Radionuclide Concentrations, Wiscasset Site, One-box Model, Normal Operation

Radionuclide	Half-life (day)	Release Rate (Ci/yr)	Radionuclide Concentration (μCi/cc)
H-3	.447(4)	3.85(2)	3.54(-11)
Cr-51	27.8	5.85(-3)	3.74(-17)
Mn-54	303	4.19(-5)	1.79(-18)
Fe-55	949	2.3(-4)	1.61(-17)
Co-58	71.3	7.20(-3)	1.07(-16)
Fe-59	45.6	3.24(-5)	3.26(-19)
Co-60	1921	9.00(-4)	7.45(-17)
Ge-78	.0613	3.31(-8)	4.98(-24)
As-78	.0632	6.50(-8)	6.00(-16)
Br-84	.0221	1.00(-3)	5.40(-21)
Rb-88	.0124	5.50(-2)	1.67(-19)
Rb-89	.0107	1.36(-3)	3.60(-21)
Sr-89	52.7	1.43(-4)	1.64(-18)
Sr-90	10110	3.19(-6)	3.08(-19)
Y-90	2.67	1.06(-4)	3.75(-19)
Sr-91	.403	8.36(-5)	8.30(-21)
Y-91	58.8	7.59(-2)	9.58(-16)
Y-93	.429	5.98(-4)	6.30(-20)
Zr-95	65.5	1.44(-6)	2.00(-20)
Nb-95	35.0	1.48(-4)	1.19(-18)
Zr-97	.708	6.60(-5)	1.14(-20)
Mo-99	2.78	4.10(-1)	2.78(-16)
Ru-103	39.5	1.16(-4)	1.02(-18)
Rh-105	1.49	1.16(-5)	5.36(-16)
Ru-106	368	4.46(-6)	2.12(-19)
Pd-109	.560	3.16(-7)	4.35(-23)
Ag-111	7.50	4.28(-7)	7.71(-22)
Cd-115	2.23	6.05(-8)	3.30(-23)
Sn-119m	.25(3)	2.04(-7)	7.57(-21)
Sn-121	1.15	1.38(-7)	3.89(-23)
Sn-123	125	1.17(-8)	2.70(-22)
Sn-125	9.40	1.30(-9)	2.93(-24)
Sb-125	989	1.03(-7)	7.30(-21)
Te-125m	58.0	1.06(-5)	1.34(-19)
Sb-126	.375	2.33(-8)	2.14(-24)

Table 20 (Continued)

Radionuclide	Half-life (day)	Release Rate (Ci/yr)	Radionuclide Concentration (μCi/cc)
Sb-127	3.88	2.84(-6)	2.68(-21)
Te-127m	109	3.90(-5)	8.26(-19)
Te-127	.392	1.65(-4)	1.50(-19)
Te-129m	34.1	2.05(-6)	1.58(-20)
Te-129	.0477	6.66(-4)	1.79(-20)
I-129	6.2(9)	1.27(-9)	1.27(-22)
Te-131m	1.25	6.55(-4)	2.00(-19)
I-131	8.05	1.08(-1)	2.09(-16)
Te-132	3.24	8.64(-3)	6.82(-18)
I-132	.0942	2.54(-1)	1.27(-17)
I-133	.846	1.40(-1)	2.90(-17)
Te-134	.0292	5.67(-4)	4.10(-21)
I-134	.0361	1.34(-2)	1.23(-19)
Cs-134	748	4.64(-1)	3.01(-14)
I-135	.278	6.19(-2)	4.22(-18)
Cs-136	13.7	3.00(-2)	9.76(-17)
Cs-137	10950	4.43	4.28(-13)
Cs-138	.0224	1.23(-1)	6.76(-19)
Ba-140	12.80	1.71(-4)	5.21(-19)
La-140	1.676	1.65(-4)	5.87(-19)
Ce-141	32.5	1.50(-4)	1.11(-18)
Ce-143	1.37	1.43(-4)	4.79(-20)
Pr-143	13.59	1.49(-4)	5.27(-19)
Ce-144	284	7.70(-5)	3.17(-18)
Pr-145	.249	2.20(-5)	1.35(-21)
Nd-147	11.1	5.10(-5)	1.35(-19)
Pm-147	62.9	1.10(-5)	1.59(-18)
Pm-149	2.21	1.93(-5)	1.04(-20)
Pm-151	1.16	6.05(-6)	1.71(-21)
Sm-151	.318(5)	7.05(-8)	6.97(-21)
Sm-153	1.95	3.64(-6)	1.74(-21)
Eu-155	661	1.14(-7)	7.06(-21)
Eu-156	15.4	3.22(-7)	5.61(-14)
Eu-157	.629	7.00(-8)	1.08(-23)
Gd-159	.750	1.24(-8)	2.28(-24)

( ) Denotes power of ten.

the sea water. Some of the bubbles will reach the surface, but only some of the noble gases such as krypton and xenon will remain and be released to the atmosphere. The radionuclides absorbed by the sea water will initially cause very high radionuclide concentrations near the site. The same dilution processes will reduce the radionuclide concentrations as in continuous release during normal operation, but at a greater rate for the accidental batch release. As in the analysis of normal release, motion of the sea water and radioactive decay are considered, but settling to the bottom, chemical reactions, and biological uptake and release are ignored. Since the bubbles rise to the surface while radionuclides are absorbed, good initial vertical mixing of radionuclides in sea water is assumed. Conservatively, all of the radionuclides released are assumed to be absorbed in the sea.

As in the normal release, the sea water motion is divided into three sizes relative to the cloud of radionuclide-laden water; viz., much larger than, comparable with, and much smaller than the size of the radionuclide cloud. The shape of this cloud as it is carried down current can be surmised from experimental instantaneous releases of dye in the ocean. Two shearing effects will tend to give the cloud a long tail similar to that of a comet: the velocity gradient from the surface to the bottom, and the velocity gradient across the current. Photographs and worthy discussions on the shape of dye patches can be found in references 1 and 2. Eddies of comparable size, spurs from adjoining currents, wind-driven currents, tides, and countercurrents at different depths easily distort the shape of the cloud of radionuclide-containing water. However, the principal means of mixing is small eddy diffusion.

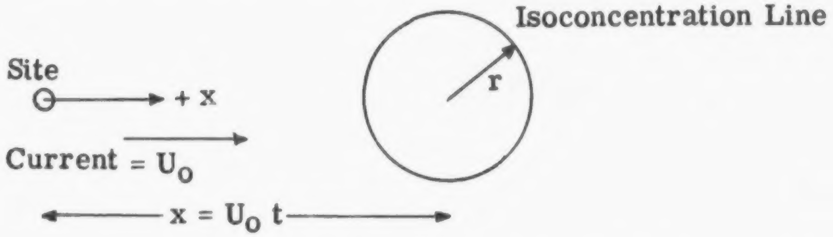
In this analysis, a uniform current past the site and small eddy diffusion are considered as the only effects on the cloud of radionuclide-laden water. The currents that produce an asymmetric shape of the cloud are ignored. This assumption is conservative since some mixing processes are being ignored.

The radionuclide concentrations are calculated from 1 to 40 nautical miles downstream from the site. This range is chosen because it is beyond the range of mechanical mixing near the site, but does not exceed the practical limit of the analytical model.

The model chosen for the mixing analysis of the batch release in the sea, assumes a normal or Gaussian distribution radially, with the center of the cloud traveling with the current as described in references 1 and 3. More complex models are available, but are not suitable for this engineering study for reasons given under the description of radionuclide distribution for normal release.

Theory

The following sketch shows a circular isoconcentration line down current from the site which is the plus x-direction.



The following derivation assumes constant concentration over depth, and initially assumes negligible decay (half-life > 100 days). Assume the radionuclide concentration to be Gaussian in the radial direction:

$$\phi_{(x,r)} = \phi_{(x,0)}\, e^{-\frac{r^2}{2\sigma_r^2}}$$

where:

$\phi(x,r)$ = radionuclide concentration (μ Ci/cc) at location x, r
$\phi(x,0)$ = radionuclide concentration (μCi/cc) at center of cloud
σ_r = standard deviation in the radial direction

Assume the standard deviation, σ_r, proportional to the downstream distance, x, which implies mixing is proportional to distance regardless of current velocity:

$$\sigma_r = cx$$

where c is a constant.

Substituting:

$$\phi(x,r) = \phi(x,0)\, e^{-\frac{r^2}{2c^2x^2}}$$

By conservation of radionuclides:

$$Q = \int_0^\infty \varphi(x,r)\, 2\pi r D dr = 2\pi D \phi(x,0) \int_0^\infty e^{-\frac{r^2}{2c^2x^2}} rdr$$

where

Q = total radionuclide release (curies)
D = depth of water

$$Q = 2\pi Dc^2x^2\, \phi(x,0)$$

Solving for $\phi(x,0)$:

$$\phi(x,0) = \frac{Q}{2\pi Dc^2x^2}$$

Substituting:

$$\phi(x,r) = \frac{Q}{2\pi Dc^2x^2}\, e^{-\frac{r^2}{2c^2x^2}}$$

This empirical formula is recommended by Okubo and Pritchard on page 39 of reference 1, and is recommended and verified with experimental data on dye releases in reference 3. A value of c = 0.1 was determined to fit best with experimental data in reference 3.

This basic equation must be modified to include radioactive decay for decay chains of up to three radionuclides. The following formulas for the ith radionuclide concentration in the decay chain are derived in appendix C:

$$\phi_i(x,r) = \frac{f_i(x)}{2\pi Dc^2x^2}\, e^{-\frac{r^2}{2c^2x^2}}$$

where $f_1(x) = Q_1 e^{-\frac{\lambda_1 x}{U_o}}$

for the first of a 1, 2, or 3-radionuclide chain, where

$$f_2(x) = \frac{\lambda_2 Q_1 f_{d2}}{\lambda_2 - \lambda_1}\left(e^{-\frac{\lambda_1 x}{U_o}} - e^{-\frac{\lambda_2 x}{U_o}}\right) + Q_2 e^{-\frac{\lambda_2 x}{U_o}}$$

for the second of a 2 or 3-radionuclide chain, where:

$$\begin{aligned} f_3(x) = {} & \frac{\lambda_3 \lambda_2 Q_1 f_{d2} f_{d3}}{(\lambda_3 - \lambda_2)(\lambda_2 - \lambda_1)}\left(e^{-\frac{\lambda_3 x}{U_o}} - e^{-\frac{\lambda_2 x}{U_o}}\right) \\ & - \frac{\lambda_3 \lambda_2 Q_1 f_{d2} f_{d3}}{(\lambda_3 - \lambda_1)(\lambda_2 - \lambda_1)}\left(e^{-\frac{\lambda_3 x}{U_o}} - e^{-\frac{\lambda_1 x}{U_o}}\right) \\ & + \frac{\lambda_3 Q_1 (1-f_{d2})}{\lambda_3 - \lambda_2}\left(e^{-\frac{\lambda_1 x}{U_o}} - e^{-\frac{\lambda_1 x}{U_o}}\right) \\ & + \frac{\lambda_3 Q_2 f_{d3}}{\lambda_3 - \lambda_2}\left(e^{-\frac{\lambda_2 x}{U_o}} - e^{-\frac{\lambda_3 x}{U_o}}\right) \\ & + Q_3 e^{-\frac{\lambda_3 x}{U_o}} \end{aligned}$$

for the third radionuclide in a chain, where:

λ_i = decay constant of the i^{th} (day^{-1}) radionuclide = .693/half-life

U_o = downstream current velocity (nm/day)

f_{d2} = decay fraction of first to second radionuclide, $(1-f_{d2})$ decays directly to the third radionuclide

f_{d3} = decay fraction of second to third radionuclide $(1-f_{d3})$ decays directly to the stable nuclide.

The formula for the average radionuclide concentration, $\overline{\phi}(x,r)$, within a circle of radius r is derived as follows for the i^{th} radionuclide:

$$\bar{\phi}_i(x,r) = \frac{\int \phi_i(x,r)dv}{\int dv}$$

Substituting:

$$\bar{\phi}_i(x,r) = \frac{\frac{f_i(x)}{2\pi Dc^2x^2} \int_0^r e^{-\frac{r^2}{2c^2x^2}} 2\pi rDdr}{\pi r^2D}$$

$$\bar{\phi}_i(x,r) = \frac{f_i(x)}{\pi r^2D}\left(1 - e^{-\frac{r^2}{2c^2x^2}}\right)$$

Radionuclide Concentrations for Nuclear Accidents

The iso- and average concentrations and average specific activities are given, for each radionuclide released in the loss-of-coolant accident and in the breach-of-containment accident, in appendix D. Data are given for three current velocities: 0.5, 4.0, and 24.0 nm/day. Concentrations are highest for the greatest velocity, unless the half-life of the nuclide or precursor is long, in which case concentrations become equal. The depth is 200 feet = .0329 nm. Concentrations are calculated for 1, 2, 4, 10, 20, and 40 nm down current and for radii corresponding to r/x ratios of 0.05, 0.1, and 0.2. The volume of water within each isoconcentration curve is also presented.

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3. N. Ito, M. Fukuda, and Y. Tanigawa, "Small-Scale Horizontal Diffusion Near the Coast," Symposium on the Disposal of Radioactive Wastes into Seas, Oceans, and Surface Waters, IAEA, Vienna, 1966, STI/PBU/126.

Section 8

EFFECT OF RADIONUCLIDES ON MAN AND MARINE BIOTA

This section presents the results of the study made to ascertain the effect of radionuclides released from an underwater nuclear power plant on man and marine biota. Radionuclide release used in this study is typical of that from a pressurized water reactor in current commercial operation. We take as a guiding principle for this study the following quotation from Handbook 69 (reference 1): "Because of the many assumptions and approximations made in applying much of the data in this publication, it is concluded that detailed refinements in the calculations generally are unwarranted." In other words, equal accuracy of calculations throughout the analysis avoids spending a disproportionately large amount of time on one part of the analysis. It is assumed that a conservative yet realistic approach will yield an estimated annual dose in which the conservatisms will have more than balanced the unknowns, but not excessively so. Assurance that this balance occurs is provided by the procedure of applying individual conservatisms to individual unknowns, although this procedure often results in an excessively conservative estimated annual radiation dose.

An evaluation of the biological effect of radionuclides on man and marine biota must begin with a qualitative description of the physical and biological processes involved in transporting the radionuclides from the sea water to man. Since radionuclides of an element are chemically indistinguishable from the stable nuclides of the same element, each radionuclide will be transported from organism to organism as its element progresses through a food chain that may end with man. A typical food chain begins with uptake of the element by phytoplankton or zooplankton from the sea water. The plankton may be eaten by copepods or other microscopic crustaceans which, in turn, may become food for small fish such as smelt. The element might then pass from the smaller fish to mackerel, to tuna, to man. Other food chains end with large crustaceans such as lobsters or crabs. Molluscs such as clams, oysters, and scallops, filter the plankton from the sea water at the bottom, where radionuclides in the sediment might contribute to mollusc uptake. Radionuclides in the sediment are taken up and concentrated by marine algae or seaweed, and may also end in man. Kelp, for instance, is harvested on the Pacific Coast for use in chemical industries. A gelatinous extract from seaweeds is also used to thicken ice cream and in cosmetics.

A multitude of food chains exist and are interrelated to form food webs. Little quantitative information about intake rates and retention of radionuclides by marine organisms in the food web is available in the literature. Many organisms in the web concentrate the elements, since the elements are necessary for biological functions. Consequently, the concentrations of radionuclides in marine organisms are usually greater than in the sea water.

Part of the contaminated food eaten by an organism is assimilated and part passes through its digestive system. Concurrently, radionuclides are being eliminated from the organism at a rate proportional to the concentration of the radionuclide within the organism. If an adult organism remains in contaminated water for a long enough time, the concentration of a radionuclide in the organism will reach an equilibrium whereat the rate of assimilation equals the rate of elimination of that radionuclide. The time that it takes for the radionuclide concentration in the organism to reach one half of this equilibrium value is called the biological half-life of the organism for that radionuclide. The rate of radionuclide transport to man is determined by the rate of assimilation of each organism, competing with the rates of dilution and radioactive decay. Dilution occurs in two ways: dilution by sea water, and "market dilution," which refers to dilution by consumption of uncontaminated with contaminated food by all marine organisms and man. Growing organisms have a greater assimilation rate than adult organisms, but their elimination rate is not shortened. It is possible for a growing organism to increase its radionuclide concentration in the higher concentration regions after an accidental release, and have higher concentrations relative to surrounding water for a period thereafter. Although internal radiation dosage from ingested radionuclides is the more serious possibility, an external dose might be received by a commercial fisherman from handling fishing gear that had dragged through contaminated silt. One might also receive external dosage by lying on contaminated beach sand.

The chemical form of the radionuclide determines its path through the food web. If the radionuclide is in the same chemical form as the naturally occurring element, the radionuclide and element are indistinguishable. If the chemical form of the radionuclide differs from that of the element, the paths may differ, either increasing or decreasing the effect on man. For example, a chemically different radionuclide might preferentially adsorb onto particulate matter such as silt or microorganisms. The silt would settle to the bottom and might not be a hazard, but the microorganisms might be selectively eaten by other biota and thus bypass some dilution by the naturally occurring element.

There are two methods of analyzing the effect of radionuclides on man: by concentration factors, or by specific activity as described below.

CONCENTRATION FACTOR METHOD

Maximum permissible concentrations of radionuclides in sea water (MPCC) can be calculated from maximum permissible concentrations in drinking water (MPC_W), with concentration factors for marine food webs. A complete explanation of this concept is given by A. M. Freke (reference 2), and is summarized as follows. Maximum permissible concentrations in μCi/cc of radionuclides in drinking water are given in Handbook 69 (reference 1) for occupational exposure. These MPC_W's are recommended by the International Commission on Radiological Protection (ICRP), Committee II on Permissible Dose for Internal Radiation (reference 3). The lowest value of the MPC_W (which defines the critical organ) for a 168-hr week is used for each radionuclide in this study. To keep the average dose to the general public as low as possible, the MPC_W's for radiation workers are reduced by a factor of ten. The MPC_W's are based on a daily intake of 2200 cc of water continuously over 50 years so that the average annual dose from a single radionuclide equals the maximum annual dose to the critical organ. If more than one radionuclide is ingested, its fraction of MPC_W must be added for each organ and compared with 1.0.

The maximum daily intake of a radionuclide in μCi/day is:

$$\frac{MPC_W}{10} \cdot 2200$$

Assume the daily protein requirement of an individual is 1-gm protein per kg body weight. The body weight of the standard man is 70 kg as adopted by the ICRP. Each class of seafood -- fish, crustacean, mollusc, or edible seaweed -- has a protein content expressed as P_c, a percentage of seafood weight. The daily intake in grams/day of a particular seafood that is assumed to supply the entire protein requirement to the standard man is:

$$\frac{1\ \text{gm}}{\text{kg}} \cdot 70\ \text{kg} \cdot \frac{100}{P_c}$$

For fish, which is 17.5 percent protein, the daily intake is 400 gm, or about 0.9 lb. The maximum permissible concentration of radionuclides in a particular class of seafood, MPC_{sf} in μCi/gm, is calculated by dividing the maximum permissible daily intake of radionuclides by the maximum daily intake of seafood giving:

$$MPC_{sf} = \frac{MPC_w\ 2200\ P_c}{10 \cdot 70 \cdot 100}$$

Concentration factors for fish, crustacea, mollusks, and edible seaweed have been tabulated by Freke (reference 2). The concentration factor is defined as the number of microcuries per gram of seafood divided by the number of microcuries per gram of sea water in which the seafood is assumed to have existed for sufficient duration that all organisms in the food web have effectively reached biological equilibrium. Assuming that the approximate density of sea water is 1 gm/cc, the formula for the maximum permissible concentration in sea water for each radionuclide is:

$$MPCC = \frac{MPC_w\ \ 2200\ \ P_c}{10 \cdot 70 \cdot 100\ C_f}$$

where:

$MPCC$ = maximum permissible concentration (μCi/cc) of a radionuclide in sea water

MPC_w = maximum permissible concentration (μCi/cc) of a radionuclide in drinking water as recommended by the ICRP for 168-hr/week occupational exposure to the critical organ

P_c = percent protein content for the particular class of seafood

C_f = concentration factor for the radionuclide from sea water to seafood per unit mass of each.

The average protein content for each class of seafood by weight percentage is tabulated below. In the cases of fish, crustacea, and mollusks, the protein content is given for the flesh only.

Average Protein Content for Marine Organisms

Organism	Protein Content of Edible Portion (Weight %) (Reference 2)
Fish	17.5
Crustacea	16.0
Molluscs	6.0
Algae	50.0

The possibility of exposure of individuals to an external radiation dose from silt (commercial fisherman dragging the bottom or bather on a mud flat) must be considered. The method of calculating the dose rate is that presented by Freke in reference 2. Based on the permissible dose rate to the general public of 0.5 rem in one year, and assuming that the exposure time might be as high as 1000 hours, the allowable dose rate is:

$$\frac{0.5}{1000} = 5 \times 10^{-4} \text{ rem/hr}$$

The dose rate in rem/hr from a plane surface of an infinitely thick layer of uniformly contaminated silt is approximately equal to:

$$CE$$

where:

C = specific activity of contaminated material (μCi/gm)
E = effective energy per disintegration (Mev)

Assuming that the effective decay gamma energy per disintegration of the radionuclide is 1 Mev, the specific activity of the silt would be:

$$5 \times 10^{-4} \ \mu\text{Ci/gm}$$

If the concentration factor from sea water to silt is C_f, the formula for MPCC from external radiation becomes:

$$\text{MPCC} = \frac{5 \times 10^{-4}}{C_f} \ \mu\text{Ci/cc}$$

Following Freke's example, the concentration factor from sea water to silt is arbitrarily assumed equal to the concentration factor from sea water to mollusc. Since the mollusc may live in the silt, we are assuming that mollusc and silt each have the same specific activity per gram.

The calculation of the MPCC's for all radionuclides is given in table 21. The organism having the highest concentration factor (fish, crustacean, mollusc, or algae) and that for silt is also given. The concentration factor and the MPC_w are given. Note that the concentration factor for fish is not the highest for any radionuclide, yet man probably consumes more fish than other marine organisms.

Concentration factors have been compiled by Polikarpov (reference 12) for many varieties of marine organisms, and for many parts of the higher forms; e.g., muscles, bones, blood, eggs, etc. These detailed concentration factors were not used in this study because they represent the next level of sophistication in analysis of radionuclides in the sea.

SPECIFIC ACTIVITY METHOD

The specific activity method has the advantage of establishing maximum permissible radiation levels in the sea, without requiring knowledge of the food web. Complete explanations of this concept are found in references 4 and 5; a summary is given here. There are two maximum permissible quantities given in Handbook 69 (reference 1) as recommended by the ICRP (reference 3). These quantities are the maximum permissible concentration in drinking water (MPC_w) which is discussed in the section on concentration factors, and the maximum permissible body burden (MPBB), in microcuries, for various "organs" in the human body. The maximum permissible specific activity (MPSA) in μCi/gm is defined as the maximum permissible burden in microcuries of radionuclide in the critical organ, divided by the average number of grams of the element in the critical organ. The specific activity of each radionuclide in the sea can be calculated by dividing the concentration of the radionuclide in microcuries per cc of sea water by the natural concentration of the element in grams per cc of sea water.

Since neither the human body nor any marine organism is an isotope separator, the proportion of radionuclide to element will not increase as the radio-

Table 21. Maximum Permissible Concentration of Radionuclides in Sea Water (MPCC)

Derivation: Algae $$\text{MPCC} = 1.58\left(\frac{\text{MPC}_w}{C_f}\right)\ \mu\text{Ci/cc}$$

Crustacea $$\text{MPCC} = .504\left(\frac{\text{MPC}_w}{C_f}\right)$$

Molluscs $$\text{MPCC} = .189\left(\frac{\text{MPC}_w}{C_f}\right)$$

Silt $$\text{MPCC} = \frac{5 \times 10^{-4}}{C_f}$$

Nuclide	Organism	MPC_w	Conc. Factor C_f	MPCC (μCi/cc)
H-3	Algae	.03	1	$4.7\text{x}10^{-2}$
Cr-51	Silt	--	10^3	$5.0\text{x}10^{-7}$
Mn-54	Molluscs	10^{-3}	$5\text{x}10^4$	$3.8\text{x}10^{-9}$
Fe-55	Silt	--	$2\text{x}10^4$	$2.5\text{x}10^{-8}$
Co-58	Crustacea	$9\text{x}10^{-4}$	10^4	$2.3\text{x}10^{-8}$
Fe-59	Molluscs	$5\text{x}10^{-4}$	$2\text{x}10^4$	$4.7\text{x}10^{-9}$
Co-60	Crustacea	$3\text{x}10^{-4}$	10^4	$1.5\text{x}10^{-8}$
Ge-78	--	--	--	--
As-78	--	--	--	--
Br-84	--	--	--	--
Rb-88	--	--	--	--
Rb-89	--	--	--	--
Sr-89	Algae	10^{-4}	20	$7.9\text{x}10^{-6}$
Sr-90	Algae	10^{-6}	20	$7.9\text{x}10^{-8}$
Y-90	Molluscs	$2\text{x}10^{-4}$	10^2	$3.8\text{x}10^{-7}$
Sr-91	Algae	$5\text{x}10^{-4}$	20	$4.0\text{x}10^{-5}$
Y-91	Molluscs	$3\text{x}10^{-4}$	10^2	$5.7\text{x}10^{-7}$
Y-93	Molluscs	$3\text{x}10^{-4}$	10^2	$5.7\text{x}10^{-7}$
Zr-95	Algae	$6\text{x}10^{-4}$	10^3	$9.5\text{x}10^{-7}$
Nb-95	Molluscs	10^{-3}	$2\text{x}10^2$	$9.5\text{x}10^{-7}$
Zr-97	Algae	$2\text{x}10^{-4}$	10^3	$3.2\text{x}10^{-7}$
Mo-99	Molluscs	$4\text{x}10^{-4}$	10^2	$7.5\text{x}10^{-7}$
Ru-103	Algae	$8\text{x}10^{-4}$	10^3	$1.3\text{x}10^{-6}$
Rh-105	Molluscs	10^{-3}	10^2	$1.9\text{x}10^{-6}$
Ru-106	Algae	10^{-4}	10^3	$1.6\text{x}10^{-7}$

Table 21 (Continued)

Nuclide	Organism	MPC$_w$	Conc. Factor C$_f$	MPCC (μCi/cc)
Pd-109	Molluscs	7x10^{-4}	10^{2}	1.3x10^{-6}
Ag-111	Molluscs	4x10^{-4}	5x10^{3}	1.5x10^{-8}
Cd-115	Molluscs	3x10^{-4}	10^{4}	5.7x10^{-9}
Sn-119m	--	--	--	--
Sn-121	--	--	--	--
Sn-123	--	--	--	--
Sn-125	Algae	2x10^{-4}	10	3.2x10^{-5}
Sb-125	Algae	10^{-3}	10^{4}	1.6x10^{-7}
Te-125m	Algae	10^{-3}	10^{3}	1.6x10^{-6}
Sb-126	--	--	--	--
Sb-127	--	--	--	--
Te-127m	Algae	6x10^{-4}	10^{3}	9.5x10^{-7}
Te-127	Algae	2x10^{-3}	10^{3}	3.2x10^{-6}
Te-129m	Algae	2x10^{-4}	10^{3}	3.2x10^{-7}
Te-129	Algae	8x10^{-3}	10^{3}	1.3x10^{-5}
I-129	Algae	4x10^{-6}	10^{4}	6.3x10^{-10}
Te-131m	Algae	4x10^{-4}	10^{3}	6.3x10^{-7}
I-131	Algae	2x10^{-5}	10^{4}	3.2x10^{-9}
Te-132	Algae	2x10^{-4}	10^{3}	3.2x10^{-7}
I-132	--	6x10^{-4}	--	--
I-133	Algae	7x10^{-5}	10^{4}	1.1x10^{-8}
Te-134	--	--	--	--
I-134	Algae	10^{-3}	10^{4}	1.6x10^{-7}
Cs-134	Crustacea	9x10^{-5}	50	9x10^{-7}
I-135	Algae	2x10^{-4}	10^{4}	3.2x10^{-8}
Cs-136	Crustacea	6x10^{-4}	50	6.0x10^{-6}
Cs-137	Crustacea	2x10^{-4}	50	2x10^{-6}
Cs-138	--	--	--	--
Ba-140	Algae	2x10^{-4}	10^{2}	3.2x10^{-6}
La-140	Molluscs	2x10^{-4}	10^{2}	3.8x10^{-7}
Ce-141	Molluscs	9x10^{-4}	10^{2}	1.7x10^{-6}
Ce-143	Molluscs	4x10^{-4}	10^{2}	7.6x10^{-7}
Pr-143	Molluscs	5x10^{-4}	10^{3}	9.5x10^{-8}
Ce-144	Molluscs	10^{-4}	10^{2}	1.9x10^{-7}
Pr-145	--	--	--	--
Nd-147	Molluscs	6x10^{-4}	10^{3}	1.1x10^{-7}
Pm-147	Molluscs	2x10^{-3}	10^{3}	3.8x10^{-7}
Pm-149	Molluscs	4x10^{-4}	10^{3}	7.6x10^{-8}
Pm-151	--	--	--	--
Sm-151	Silt	--	10^{3}	5x10^{-7}

Table 21 (Continued)

Nuclide	Organism	MPC_w	Conc. Factor C_f	MPCC (μCi/cc)
Sm-153	Molluscs	$8x10^{-4}$	10^3	$1.5x10^{-7}$
Eu-155	Molluscs	$2x10^{-3}$	10^3	$3.8x10^{-7}$
Eu-156	--	--	--	--
Eu-157	--	--	--	--
Gd-159	Molluscs	$8x10^{-4}$	10^3	$1.5x10^{-7}$

nuclide passes through the food web to man. If the specific activities of the radionuclides in the sea, in places where food organisms develop and dwell, can be maintained below the maximum permissible specific activities of these radionuclides in man, an individual cannot exceed the allowable radiation dose by consumption of marine products.

The formula for the MPSA is derived as follows: The MPBB given in Handbook 69 is the total number of μCi in all organs of the body, and is such that the fraction of the MPBB in the organ of reference produces the maximum annual dose to that organ for radiation workers. Each element has a natural distribution among the organs of the body, depending on the chemical affinity of each element for each organ. The fraction of each radionuclide in the "organ-of-reference" to that in the whole body is given as f_2 in table 12 of reference 3. The MPSA is calculated using the MPBB of the critical organ, which is the organ having the lowest MPC_w. The maximum permissible burden in the critical organ in μCi for the general public is:

$$\frac{MPBB}{10} \quad f_2$$

in which the MPBB for occupational exposure is reduced by a factor of 10 for application to the general public. The number of grams of the carrier element in the critical organ equals the product of the mass of the critical organ in grams, g, times the average concentration, C in grams, of the element per gram of wet tissue of the critical organ: g C. Both g and C are found in table 12 of reference 3. The MPSA without the decay factor becomes:

$$\frac{MPBB \cdot f_2}{10\ g\ C}$$

If man slowly assimilates a radionuclide that has a physical half-life which is short in comparison with its biological half-life in man, natural decay during the slow assimilation process will produce a specific activity in the critical organ less than the specific activity of the seafood consumed. A decay factor which is the ratio of SA in the organ divided by the SA in the seafood has been derived for man in reference 4, and equals:

$$\frac{\lambda + B}{B}$$

where:

λ = physical decay constant (day^{-1})(λ = .693/physical half-life)
B = biological decay constant (day^{-1})(B = .693/biological half-life)

If the physical half-life is long relative to the biological half-life, the decay factor approaches 1.0. Including the decay factor for man, the MPSA formula is then:

$$\text{MPSA} = \frac{\text{MPBB } f_2}{10 \text{ g C}} \cdot \frac{\lambda + B}{B}$$

where:

MPSA = maximum permissible specific activity (μ Ci/gm) for the general public
MPBB = maximum permissible body burden (μ Ci) for occupational exposure
f_2 = fraction of radionuclide in the critical organ
g = mass of critical organ (gm)
C = concentration of carrier (gm/gm wet tissue) in critical organ
10 = factor to reduce allowable radiation level from radiation worker to general public. This factor should be 100 for H_3, C, S, V, Fe, Co, Cu, and Zn Because of differences in their chemical form (see subsection below on relative merits of methods)

The calculated values of the MPSA are given in table 22.

Table 22. Calculation of Maximum Permissible Specific Activity (MPSA)

① Radionuclide	② Carrier	③ Critical "Organ"	MPBB (μCi)	Fraction of ① in ③	MPB in ③ (μCi)	Mass of ③ (gm)	Conc. ② in ③ (gm/gm)	Quantity ② in ③ (gm)	No-decay MPSA (μCi/gm)	Physical Half-life (days)	Biological Half-life (days)	Decay Factor $\frac{\lambda + B}{B}$	MPSA (μCi/gm)
H-3	H	Body tissue	1x10^{3}	1.0	1x10^{3}	4.3x10^{4}	.16*	6.88x10^{3}	.00145#	4.5x10^{3}	12	1.0	.00145
Cr-51	Cr	(Total body)***	(800)***	(1.0)	800	7.0x10^{4}	8.6x10^{-8}	.0060	(13,300)***	27.8	616	23.1	(3.07x10^{5})***
Mn-54	Mn	(Total body)	(40)	1.0	40	7x10^{4}	3x10^{-7}	.021	(190)	300	17	3.04	(578)
Fe-55	Fe	Spleen	1x10^{3}	.02	20	150	5.3x10^{-4}	.080	2.52#	1.1x10^{3}	600	1.54	3.88
Co-58	Co	(Liver)	(200)	.02	4.0	1.7x10^{3}	3x10^{-7}	.00051	(78.5)#	72	9.5	1.13	(88.7)
Fe-59	Fe	(Total body)	(20)	1.0	20	7x10^{4}	5.7x10^{-5}	4.0	(.050)#	45.1	800	18.7	(.887)
Co-60	Co	(Total body)	(10)	1.0	10	7x10^{4}	<4.3x10^{-8}	.0030	(33.2)#	1.9x10^{3}	9.5	1.0	(33.2)
Ge-78	--	--	--	--	--	--	--	--	--	--	--	--	--
As-78	--	--	--	--	--	--	--	--	--	--	--	--	--
Br-84	--	--	--	--	--	--	--	--	--	--	--	--	--
Kr-85m	--	--	--	--	--	--	--	--	--	--	--	--	--
Kr-85	--	--	--	--	--	--	--	--	--	--	--	--	--
Kr-87	--	--	--	--	--	--	--	--	--	--	--	--	--
Kr-88	--	--	--	--	--	--	--	--	--	--	--	--	--
Rb-88	--	--	--	--	--	--	--	--	--	--	--	--	--
Rb-89	--	--	--	--	--	--	--	--	--	--	--	--	--
Sr-89	Sr	Bone	4	.99	4	7x10^{3}	1.9x10^{-5}*	.133	3.0	50.5	1.8x10^{4}	357	1070
Sr-90	Sr	Bone	2	.99	2	7x10^{3}	1.3x10^{-5}*	.133	1.5	10^{4}	1.8x10^{4}	2.81	4.22
Y-90	RE	(Bone)	(3)	.75	2.25	7x10^{3}	7.2x10^{-6}*	.0504	(4.47)	2.68	1.8x10^{4}	6.72x10^{3}	(3.0x10^{4})
S-91	Sr	(Bone)	(3)	.76	2.28	7x10^{3}	1.9x10^{-5}*	.133	(1.72)	0.4	1.8x10^{4}	4.5x10^{4}	(7.75x10^{4})
Y-91	RE	(Bone)	(5)	.75	3.75	7x10^{3}	7.2x10^{-6}*	.0504	(7.45)	58	1.8x10^{4}	310	(2310)
Y-93	RE	(Bone)	(2)	.75	1.50	7x10^{3}	7.2x10^{-6}*	.0504	(2.98)	.42	1.8x10^{4}	4.3x10^{4}	(1.28x10^{5})
Zr-95	Zr	(Liver)	(40)	.07	2.8	1.7x10^{3}	<10^{-6}	.0017	(165)	63.6	320	6.05	(1000)
Nb-95	Nb	(Total body)	(40)	1.0	40	7x10^{4}	<7x10^{-7}	.049	(81.6)	35	760	22.7	(1850)
Zr-97	Zr	(Liver)	(10)	.07	0.7	1.7x10^{3}	<10^{-6}	.0017	(41.1)	0.71	320	450	(1.85x10^{4})
Mo-99	Mo	Liver	20	.15	3.0	1.7x10^{3}	1.1x10^{-6}	.00187	160	2.79	45	16.9	2700
Ru-103	--	GI**	--	--	--	--	--	--	--	--	--	--	--
Rh-105	--	GI	--	--	--	--	--	--	--	--	--	--	--
Ru-106	--	GI	--	--	--	--	--	--	--	--	--	--	--
Pd-109	--	GI	--	--	--	--	--	--	--	--	--	--	--
Ag-111	Ag	(Total body)	(50)	1.0	50	7x10^{4}	8.8x10^{-5}	6.15	(.811)	7.5	5	1.67	(1.35)
Cd-115	Cd	(Kidney)	(5)	0.1	0.5	300	3.2x10^{-5}	.0096	(5.20)	2.2	300	136	(710)
Sn-119m	--	--	--	--	--	--	--	--	--	--	--	--	--
Sn-121	--	--	--	--	--	--	--	--	--	--	--	--	--
Sn-123	--	--	--	--	--	--	--	--	--	--	--	--	--
Sn-125	Sn	(Bone)	(7)	.35	2.45	7x10^{3}	<1.3x10^{-6}	.0091	(26.9)	9.5	100	11.5	(309)
Sb-125	Sb	(Total body)	(60)	1.0	60	7x10^{4}	<1.3x10^{-6}	.091	(66.0)	876	38	1.05	(70)
Te-125m	Te	Liver	100	.08	8.0	1.7x10^{3}	10^{-3}	1.7	.470	58	30	1.50	.705
Sb-126	--	--	--	--	--	--	--	--	--	--	--	--	--
Sb-127	--	--	--	--	--	--	--	--	--	--	--	--	--

RE: rare earth (Y is carrier)

**GI: gastrointestinal tract.

***Parentheses indicate that Handbook 69 lists the GI tract as the critical "organ"

*From NAS-895 (reference 4) which has the note: "These concentrations are assumed greater than average due to inconsistent data."

Table 22 (Continued)

① Radionuclide	② Carrier	③ Critical "Organ"	MPBB (μCi)	Fraction of ① in ③	MPB in ③ (Ci)	Mass of ③ (gm)	Conc. ② in ③ (gm/gm)	Quantity ② in ③ (gm)	No-decay MPSA (μCi/gm)	Physical Half-life (days)	Biological Half-life (days)	Decay Factor $\frac{\lambda+B}{B}$	MPSA (μCi/gm)
Te-127m	Te	Liver	50	.09	4.5	1.7×10^{3}	10^{-3}	1.7	.265	105	30	1.30	.346
Te-127	Te	(Liver)	(100)	.05	5.0	1.7×10^{3}	10^{-3}	1.7	(.294)	.39	30	77	(22.6)
Te-129m	Te	(Liver)	(20)	.08	1.6	1.7×10^{3}	10^{-3}	1.7	(.0941)	33	30	1.88	(.177)
Te-129	Te	(Liver)	(40)	.09	3.6	1.7×10^{3}	10^{-3}	1.7	(.118)	.051	30	589	(69.4)
I-129	I	Thyroid	3	.2	.6	20	4×10^{-4}	.008	7.5	6.3×10^{9}	138	1.0	7.5
Te-131m	Te	(Liver)	(30)	.05	1.5	1.7×10^{3}	10^{-3}	1.7	(.0882)	1.25	30	25	(2.20)
I-131	I	Thyroid	0.7	0.2	.14	20	4×10^{-4}	.008	1.75	8.0	138	18.2	31.8
Xe-131m	--	--	--	--	--	--	--	--	--	--	--	--	--
Te-132	Te	(Liver)	(20)	.06	1.2	1.7×10^{3}	10^{-3}	1.7	(.0706)	3.2	30	10.3	(.730)
I-132	I	Thyroid	0.3	0.2	.06	20	4×10^{-4}	.008	.75	.097	138	1420	1070
I-133	I	Thyroid	0.3	0.2	.06	20	4×10^{-4}	.008	.75	.87	138	158	119
Xe-133m	--	--	--	--	--	--	--	--	--	--	--	--	--
Xe-133	--	--	--	--	--	--	--	--	--	--	--	--	--
Te-134	--	--	--	--	--	--	--	--	--	--	--	--	--
I-134	I	Thyroid	0.2	0.2	.04	20	4×10^{-4}	.008	.50	.036	138	3830	1920
Cs-134	K	Total body	20	1.00	20	7×10^{4}	2×10^{-3}	140	.0143	840	70	1.08	.015
I-135	I	Thyroid	0.3	0.2	.06	20	4×10^{-4}	.008	.75	.28	138	493	370
Xe-135m	--	--	--	--	--	--	--	--	--	--	--	--	--
Xe-135	--	--	--	--	--	--	--	--	--	--	--	--	--
Cs-136	K	Total body	30	1.00	30	7×10^{4}	2×10^{-3}	140	.0214	13	70	6.36	.136
Cs-137	K	Total body	30	1.00	30	7×10^{4}	2×10^{-3}	140	.0214	1.1×10^{4}	70	1.0	.0214
Xe-138	--	--	--	--	--	--	--	--	--	--	--	--	--
Cs-138	--	--	--	--	--	--	--	--	--	--	--	--	--
Ba-140	Ba	(Bone)	(4)	.7	2.8	7×10^{3}	1.6×10^{-6}	.0112	(25.0)	12.8	65	6.08	(152)
La-140	RE	(Bone)	(10)	0.4	4	--	--	.0504	(8.0)	1.68	1000	595	(4760)
Ce-141	RE	(Bone)	(40)	0.31	12.4	--	--	.0504	(24.6)	32	1500	48.5	(1190)
Ce-143	RE	(Bone)	(10)	0.30	3.0	--	--	.0504	(6.0)	1.33	1500	1130	(6770)
Pr-143	RE	(Bone)	(20)	0.4	8.0	--	--	.0504	(16.0)	13.7	1500	110	(1760)
Ce-144	RE	(Bone)	(5)	0.38	1.9	--	--	.0504	(3.77)	290	1500	6.17	(23.3)
Pr-145	--	--	--	--	--	--	--	--	--	--	--	--	--
Nd-147	RE	(Bone)	(20)	0.35	7.0	--	--	.0504	(14.0)	11.3	1500	134	(1880)
Pm-147	RE	(Bone)	(60)	0.52	31.2	--	--	.0504	(62.0)	920	1500	2.63	(163)
Pm-149	RE	(Bone)	(20)	0.35	7.0	--	--	.0504	(14.0)	2.2	1500	682	(9540)
Pm-151	--	--	--	--	--	--	--	--	--	--	--	--	--
Sm-151	RE	(Bone)	(100)	0.78	78	--	--	.0504	(156)	3.7×10^{4}	1500	1.04	(162)
Sm-153	RE	(Bone)	(30)	0.35	10.5	--	--	.0504	(20.8)	1.96	1500	765	(15900)
Eu-155	RE	(Bone)	(80)	0.50	40	--	--	.0504	(80)	621	1500	3.42	(273)
Eu-156	--	--	--	--	--	--	--	--	--	--	--	--	--
Eu-157	--	--	--	--	--	--	--	--	--	--	--	--	--
Gd-159	RE	(Bone)	(20)	0.45	9.0	--	--	.0504	(18.0	.75	1000	1330	(24,000)

Formulae: $\text{MPSA} = \frac{1}{10*} \cdot \frac{q'}{I_{nb'}} \cdot \frac{\lambda + B}{B}$, $\lambda = \frac{1}{\text{physical half-life}}$, $B = \frac{1}{\text{biological half-life}}$

q' = MPB in ③, $I_{nb'}$ = quantity of ② in ③

*Use factor of 100 in place of 10 for H3, Cu, S, V, Fe, Co, Cu, Zn because of chemical dissimilarities between released element and natural element.

Although the usual carrier for each radionuclide is its element, often it is advantageous to group elements of common chemical properties and consider the group as the carrier. This is valid as long as the MPSA and SA in the sea are in identical units of μCi/gm of carrier. Promethium provides an example, since it does not occur naturally; i.e., it has no stable isotope. Promethium is one of the group of rare earths that are chemically similar and may be considered as a group carrier. Since data for elemental concentration in various organs exist only for yttrium, it is chosen as the carrier for the rare earths. Yttrium is included in this group because of its chemical similarity to the rare earths. Another group includes cesium with potassium. This grouping procedure is accurate, since chemically similar elements are indistinguishable in biological processes. The concentrations of elements in sea water are given in table 23.

RELATIVE MERITS OF MPCC AND MPSA

Although the MPCC and MPSA are parallel methods for the same task, there are notable differences between them. For many radionuclides that are only slightly assimilated by man, the greatest dose rate comes from the gastrointestinal tract. For them, the gastrointestinal tract is the critical "organ," and the concept of MPSA has less application. The radionuclide content of the gastrointestinal tract is determined by the concentration of radionuclides in the seafood intake upon which the MPCC concept is based.

The maximum permissible body burdens and concentrations in drinking water are conservatively established by the ICRP for a 50-year adult occupational dose. However, the ICRP emphasizes the provisional nature of their recommendations for other than the occupational dose.

The concentration factor method is approximate, since concentration factors may vary widely among a given seafood species because of variation in uptake rates, which depend on size or life-stage of the organism. Concentration factors have been observed to be constant over a wide range of concentrations. The assumption that an individual might derive his entire protein requirements from a type of seafood having the greatest concentration factor is highly unlikely and definitely cautious.

Table 23. Concentration of Elements in Sea Water

Element	Concentration (gm/cc)
H	.108
K	3.8-4
Cr	5.0-11
Mn	2.0-9
Fe	1.0-8
Co	5.0-10
Ge	7.0-11
As	3.0-9
Se	4.0-9
Br	6.5-5
Rb	1.2-7
Sr	8.0-6
Y	3.0-10
Zr	2.2-11*
Nb	1.0-11
Mo	1.0-8
Tc	--
Ru	--
Rh	--
Pd	--
Ag	3.0-10
Cd	1.1-10
Sn	3.0-9
Sb	5.0-10
Te	--
Kr	3.0-10
Xe	1.0-10
I	6.0-8
Cs	5.0-10
Ba	3.0-8
La	3.0-10
Ce	4.0-10
Pr	6.4-13*
Nd	2.8-12*
Pm	Does not occur naturally
[illegible]	4.5-13*
Eu	1.3-13*
Gd	7.0-13*

*These concentrations are from reference 14. Other concentrations are from reference 13 of which Goldberg is the source.

The addition of specific activity or concentration ratios to determine the total effect of all nuclides compounds the caution. For example, strontium may provide 50 percent of the permissible dose to the bone and 5 percent to the thyroid, while iodine may provide 50 percent of the dose to the thyroid, and 5 percent to the bone, but together these two radionuclides would provide 55 percent of the dose to the bone and thyroid instead of the 100 percent obtained by addition of dose regardless of organ. A less conservative procedure would be to add percent permissible separately for each organ.

The MPSA is more conservative than the MPCC method in that no decay factors are included in the marine food web in calculating MPSA, whereas they are inherent in the concentration factors. Ideally, a decay factor such as that applied to man should be applied to each marine organism in the food chain. Such decay factors would account for the reduction of specific activity or concentration as a result of natural radioactive decay during the time required for the radionuclide to progress through the food web to man.

The effect of "market dilution" is also ignored in both MPSA and MPCC calculations. Specific activity or radionuclide concentration is reduced by consumption of uncontaminated food along with contaminated food. Market dilution occurs for all organisms from man down to the microscopic marine organisms.

An observed nonconservatism of both MPSA and MPCC calculations is the assumption that the radionuclides behave chemically in the same manner as the carrier element. This is not always true. If the chemical form of a radionuclide on release is different from the chemical form of the carrier element in the sea, then in some cases the radionuclide adsorbs onto particulate matter and is consumed preferentially by a marine organism without the benefit of dilution by the carrier element. The MPSA method compensates by a factor of 10 for differences in chemical form that have been observed for certain elements (see section on specific activity method).

Another nonconservative assumption in both methods is that no other source of radiation dose exists for the general public besides natural background radiation. Consideration must be given to the possibility of other nuclear power plants in the neighborhood.

EFFECT ON MAN DURING NORMAL OPERATION

Although the fields of concentration in the sea have been calculated, the highest concentration, or specific activity, occurring at the condenser cooling water discharge, is used here to analyze the effect on man. This premise is highly conservative: it implies that a complete food chain exists right at the end of the cooling water discharge pipe, and that it provides an individual with his sole source of protein over the years.

Only the lowest of the two ratios, SA/MPSA or CC/PPCC, should be summed to assess the total fraction of maximum permissible dose, as may be understood by the following reasoning. If the SA of a single radionuclide exceeds the MPSA, the allowable dose to the critical organ could be exceeded if this radionuclide were so concentrated in the food web that a man's daily intake of that radionuclide exceeded permissible levels. In short, the radionuclide concentration would have to exceed the MPCC for this radionuclide. On the other hand, if the radionuclide concentration exceeds the MPCC, the allowable dose to any critical "organ" except the gastrointestinal tract would be exceeded only if the radionuclide percentage of the carrier element in the sea had previously exceeded the permissible radionuclide percentage of carrier in the critical organ. In short, the SA must also exceed the MPSA; otherwise, an individual could consume seafood having the highest radionuclide concentration and suffer no ill effects.

That the release of radionuclides from the power plant during normal operation is analyzed as being continuous, whereas in actual practice they might be released in batches as seldom as once per year, must be considered. Handbook 69 (reference 1) states that the annual occupational exposure of workers can be received over a short duration provided that no additional dose is received during the remainder of a year. The major proviso is that control must be maintained over the dose received by these workers for the rest of the year by monitoring their environmental air and water and their external radiation dose. Such control could not obtain once the radionuclides were released to the sea. Consider the possibility that a fisherman might catch his annual supply of fish from an underwater radionuclide cloud that had originated as a batch release of radionuclides. He then takes the fish home, freezes them, and eats only those fish for a full year. As highly unlikely as this is, it must be considered. Yet the annual dose to this fisherman is not expected to exceed the permissible amount. Concentrations using continuous release analysis (which assumes the eaten fish are in equilibrium with the concentration of radionuclides in the sea), are well below permissible levels (see data in next paragraph). Furthermore, the MPCC's and MPSA's are calculated for equilibrium conditions in which more radionuclides are transported to man than during the momentarily higher concentration of a batch release. For the latter, the decreasing concentration in the sea limits the effective period during which uptake and concentration processes can occur in the food web. Furthermore, the analysis presumes many conservatisms.

The fraction of permissible dose for each radionuclide of consequence taken at their discharge concentration, is given in table 24.

In conclusion, a man whose total food intake consists of organisms that derive their mineral content from the power plant discharge during normal operation, assuming no natural decay, would receive 3 percent (table 24) of his maximum permissible annual dose of 0.5 rem/yr. This received dose is extremely unlikely because of the following reasons:

1. There is natural decay.
2. Man does not subsist solely on marine life, least of all from a single location.
3. The permissible annual dose is based on a 50-year exposure (see reference 1).

Table 24. Fraction of Permissible Levels for Radionuclides at Discharge During Normal Operation

Radionuclide	CC/MPCC*	SA/MPSA*
H-3	.00011	.035
Cr-51	.00034	.000011
Mn-54	.00032	.0000010
Fe-55	.00023	.00015
Co-58	.0089	.0046
Fe-59	.00020	.00011
Co-60	.0015	.0014
Y-91	.0025	.0021
Nb-95	.0000048	.00025
Mo-99	.016	.00043
I-131	.98	.0016
Te-132	.00078	--
I-133	.37	.00056
Cs-134	.030	.0048
I-135	.056	.000081
Cs-136	.00013	.000015
Cs-137	.05	.013
Ce-144	.000016	.00043
Total	1.52	.064
Minimum Total	.030#	

*When both ratios are below .0001 the radionuclide is omitted as being inconsequential.

#The minimum total is the smaller of the two ratios for each radionuclide summed over all radionuclides.

EFFECT ON MARINE BIOTA DURING NORMAL OPERATION

No harmful effect on marine life is expected, since radionuclide concentrations or specific activities in the sea are not harmful to man. To quote Foster and Rice (reference 6):

> "The radiation dose received by fish and other aquatic forms will be greater than that received by people who drink the water or eat the fish. Even so, this does not place the fish in risk of suffering radiation damage. The radiation protection guides for people have been established with prudence, for continued exposure over a normal life span, with appropriate risk (safety) factors. Virtually all of the available evidence shows that the concentrations of radionuclides in the fish and shellfish that would limit their use as food are substantially below the concentration that would injure the organisms from radiation."

Very little experimental data is available on observed biological or ecological effects on marine life that might be caused by low concentrations of radionuclides in the sea. The following observations have been paraphrased from a paper by W. Templeton entitled "Resistance of Fish Eggs to Acute and Chronic Irradiation" (849, reference 7).

> The Russians looked at fish egg hatching mortalities in controls and in water with Sr 90 at concentrations from 1 x 10^{-9} μCi/cc to 2 x 10^{-2} μCi/cc. The proportion of abnormal fry hatched increased from 3% to 70% over this range. However, a dose from Sr 90 - Y90 of 10^{-7} μCi/cc has been calculated to be only 0.1 of the natural background dose. The English have failed to see such marked effects even at 10^{-6} to 10^{-4} in μCi/cc. Chronic doses of 10^{3} times background "produced little, if any, differences between experimental and control groups."

For the underwater power plant, the concentrations of Sr90 and Y90 at the cooling water discharge are 1.9 x 10^{-13} μCi/cc and 5.5 x 10^{-12} μCi/cc respectively, which are six orders of magnitude below background concentrations.

The lack of any Zn 65 released by the Forked River Plant is conspicuous. The reactor manufacturer assures us that this particular activation product is not present in the radioactive waste of their pressurized water plant. Zn 65 has been observed in the discharge canal of the Humboldt Bay Power Plant of the Pacific Gas and Electric Company (reference 8). This plant has a boiling water reactor. The Zn 65 was detected by using oysters, which have a concentration factor of about 10^4, and require zinc for sexual reproduction. However, it was found that because the Zn 65 concentrations were only in the range of 0.1 to 2.0×10^{-8} μCi/cc the greatest concentration that a human would derive from a protein diet of oysters raised in the canal would be well within the maximum permissible body burden.

The total radioactivity of all of the radionuclides together, except tritium, at the discharge pipe, is 1.6×10^{-7} μCi/cc. This is only half of the background radiation (3.2×10^{-7} μCi/cc), because of naturally occurring K40, which contributes 90 percent of natural background radiation in the sea.

The concentration of tritium at the discharge pipe is 5.2×10^{-6} μCi/cc, which is greatly below the maximum permissible concentration, 4.7×10^{-2} μ Ci/cc. Tritium concentrations of 7.1 μCi/cc (no exponent) in the fresh water habitat of common guppies produced no toxic effect or genetic abnormalities even to the third generation (reference 11). In this experiment, not only were all of the fish that survived normal and healthy, but 18 of the initial 20 tritiated guppies survived, as compared with 13 that survived of the initial 21 guppies in the control group, which suffered a severe infection. The possibility exists that radioactive tritium might have improved the health of the guppies by destroying infection-causing bacteria.

Maximum radionuclide concentrations of 1.2 to 2.0×10^{-6} μCi/cc of Cr 51 were observed in the Columbia River during peak years of the Hanford operation (reference 9). This maximum Cr 51 concentration caused no observable harm to marine life, and is a factor of 10^4 above the 1.7×10^{-10} μCi/cc released at the discharge of the underwater power plant. Cr 51 is not an important contributor to the activity of the underwater power plant's cooling water discharge.

Concentrations of 0.75×10^{-9} μCi/cc of Sr 90 and 0.2×10^{-9} μCi/cc of Cs 137 were detected in the Columbia River at Portland, Oregon in July 1964 (reference 9). Concentrations of 0.3×10^{-9} μCi/cc of Sr 90 and 0.8×10^{-9} μ Ci of Cs 137 were detected farther out to sea at the same time. These radionuclides were from nuclear bomb testing fallout. The underwater power plant release of Sr 90 at the discharge is 1.9×10^{-13} μCi/cc, which is well below the ocean concentrations produced by fallout. For Cs 137 it is 1.0 x 10^{-7} μCi/cc, which would be reduced to the concentration produced by fallout over large areas, within 1 nm of the site.

EFFECT ON MAN AFTER A NUCLEAR ACCIDENT

The quantity of radionuclides carried to man after a nuclear accident requires a time-dependent analysis, and knowledge of assimilation and elimination rates of the marine organisms in the food web. This data is not available in the literature. Comparison of the radionuclide concentration or specific activity in the sea water with the MPCC or MPSA is highly conservative, since the MPCC and the MPSA are derived for a steady state concentration which would not exist after the accident. However, comparison of the MPCC or MPSA with radionuclide concentrations in the sea will provide an indication of the more important radionuclides. The radionuclides 1 hr after the accident, 1 nm down current, which would have specific activities above MPSA are given in table 25.

Table 25. Important Radionuclides: 1 hr, 1-nm Down Current After Accidental Release

	Breach-of-containment Accident		Loss-of-coolant Accident	
Radionuclide	CC/MPCC	SA/MPSA	CC/MPCC	SA/MPSA
Co-58	4.9	2.5	--	--
Y-91	13.0	11.0	2.3	1.9
Nb-95	0.21	11.0	--	--
Mo-99	--	--	1.8	0.050
Ag-111	0.037	1.4	--	--
Te-129m	3.5	--	--	--
Te-131m	1.3	--	--	--
I-131	3.4×10^8	5.6×10^5	5100	8.4
Te-132	35.0	--	2.9	--
I-132	--	3200	--	--
I-133	9.7×10^7	1.5×10^5	3300	5.0
I-134	9.0×10^5	1300	130	0.18
Cs-134	140	22.0	--	--
I-135	1.9×10^7	2.7×10^4	980	1.4
Cs-137	268	67.0	--	--
La-140	--	--	3.7	0.98
Pr-143	2.0	0.36	14.0	2.4
Ce-144	0.70	19.0	5.3	140

Iodine-131 is clearly the nuclide of greatest concern in either accident. After a breach-of-containment accident, food organisms collected near the plant would probably be too contaminated for human consumption for several weeks.

A problem might arise from rapid accumulation of radioiodides by commercially harvested kelp in a nearshore area. However, that the chances of I-131 getting to man in quantity appear slim, must be emphasized. I-131 has an 8.05 day half-life, which is short relative to the total probable transport time to man, including flow time to the kelp beds, assimilation time by the kelp, harvesting time, processing time for the kelp and final product, and distribution time to man. Meanwhile, there would be market dilution by uncontaminated kelp.

Fishing would have to be curtailed following an accident. Sea water and fish would have to be monitored until sufficiently low levels were reached to resume fishing. Aside from actual radiological considerations, the economic and psychological effect on commercial fisheries and their markets over a wide area might be momentous if there were such an accident.

In summary, radioactive hazards from the breach-of-containment accident would be of concern, especially if the contaminated waters were transported ashore.

Another problem after the breach-of-containment accident would be that of salvaging the highly contaminated plant itself. Obviously, either total recovery or a suitable permanent encasement would be imperative. A good possibility exists that an effective barrier to the breach-of-containment accident can be designed and thereby prevent the more serious of the two postulated accidents.

One possible method of evaluating a nuclear accident would be to average the concentrations over a year. Handbook 69 places no restriction on timing of a dose received except that the maximum permissible dose in one year is not to be exceeded. This method was not used because of practical limitations. Factors that make it unrealistic are:

1. Fishing would be terminated for a while.
2. In marine organisms that are growing, uptake is more rapid than elimination of radionuclides from the body.

3. A single catch of fish having higher than average contamination might conceivably serve as food for a single fisherman over a whole year.

EFFECT ON MARINE BIOTA AFTER A NUCLEAR ACCIDENT

For either nuclear accident, the crucial marine organism will be the most radiosensitive animal that remains in the center of the contaminated water mass until the radionuclide concentrations have been dispersed to negligible levels. Exposure to ionizing radiations from radionuclides around the marine organisms, as well as those accumulated internally, must be considered. Since radioactive I-131 exceeds permissible levels by the greatest amount, a hazard might arise from rapid accumulation of radioiodides by marine algae. Herbivorous fishes feeding on such plants might experience the greatest thyroid injury (W. C. Hanson, "Iodine in the Environment," pp 581-601 in reference 10). Few data on the biological effects of I-131 on marine or aquatic organisms are available. For example, in the fresh water eel, Anguilla anguilla, 25 μCi/gram of body weight is considered to be a thyroid ablating dose. Larvae of the frog Hyla versicolor, immersed in a solution of 20 μCi/cc of I-131 for 24 hours showed thyroid damage.

Since ionizing radiation is proportional to the internal concentration of radionuclides, the assimilation rate must be known relative to the loss rates by decay or excretion. Some comments on the uptake of radionuclides by phytoplankton and their role in the food web are therefore appropriate. Cycling of radionuclides by phytoplankton is affected largely by:

1. Capacity of phytoplankton to ingest the radionuclide, either by adsorption to surfaces or assimilation.
2. Physical and chemical form of the radionuclide in sea water.
3. Digestibility of the phytoplankton.
4. Rate at which phytoplankton are grazed by herbivorous animals.
5. Production rate (i.e., rate of increase of new phytoplanktonic biomass).

Accumulation of radionuclides by phytoplankton depends on the physiochemical form of the radionuclides, the total concentration of the radionuclide (and metabolically similar elements in sea water), and other rates such as loss rate of the radionuclide from phytoplankton. Concerning the uptake rate of phytoplankton, Cushing at Hanford in a river study (Renfro, reference 9) states that the accumulation of some Hanford radionuclides reached steady state in a matter of hours. Rice ("Role of Phytoplankton in Radionuclide Cycling," reference 10) found that Nitzschia reached peak Ce 144 activity in one day (lab study). Corcoran and Kimball (reference 10) showed that a number of phytoplanktonic species took up Sr 90 at concentration factors of 19 to 182 (adsorption was important). Concentration of stable Sr in sea water was not so important in the laboratory conditions in which they worked.

External radiation in the water 1 hr after the breach-of-containment accident could amount to 1 to 10 rad/hr, mostly from radioiodides. All radioiodides except I-131 have half-lives of less than one day, and therefore decline to levels of a few mrad/hr in 10 days. I-131 decays more slowly (8.05-day half-life), and continues to contribute external radiation for a longer period. The integrated external dose would not exceed 1000 rad, which is several times lower than external doses to marine organisms that have produced observed lethality. Internal dose might be more important than external, but not by much: for organisms of a size smaller than the effective range of the ionizing radiation emitted in natural decay, it matters little whether the source is internal or external, depending on the degree of radionuclide concentration by the organisms. If a lethality hazard exists with marine organisms, it will be caused by exposures to contaminated water during the first 10 weeks after the breach-of-containment accident, for beyond this time all radionuclide concentrations will have dropped below MPCC and MPSA levels.

CONCLUSIONS

No harmful effects on man or marine biota are expected from normal radionuclide release from the underwater nuclear power plant. The activity of coolant discharge water from all of the radionuclides released is at most one half of the natural K40 activity in the sea.

Harmful effects on marine biota are possible for a 10-week period after a nuclear accident. A period of suspended fishing can prevent these immediate effects from reaching man. Even if steady-state conditions were assumed to prevail after a major nuclear accident, which would not be the case, the radionuclide concentrations and specific activities in the sea, as related to "maximum permissible" standards (which are conservative in themselves) would not constitute a grave menace to man.

The analysis has been done without provision for radiation doses to man from other sources such as medical (x-ray) exposure or from other coastal nuclear power plants. However, radionuclide concentrations in the sea are presented (appendix D) from which estimates can be made of the radionuclide concentrations from multiple power plants.

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Section 9
RESEARCH NEEDS

THERMAL DIFFUSION

Present technology is inadequate in some respects for accurately predicting the thermal field caused by discharging condenser cooling water into relatively deep ocean water. The turbulent, buoyant jet rises, and at some point begins spreading, to form either a submerged or surface field, depending on temperature stratification in the ocean and the degree of jet dilution. There are no available analytical methods nor experimental results that can be used to accurately describe the transition region and the spreading field, which can be quite extensive, to be at an acceptably low temperature. The submerged field is not as important ecologically, because it will only remain submerged if it is at the ambient temperature of a given stratum. To accurately predict the surface field, it is recommended that the interaction of a turbulent buoyant jet and a free surface be studied both analytically and experimentally.

Another matter that requires further work is the effect of ocean currents on a buoyant jet. As presented in appendix B, the problem can be treated analytically; however, the results depend on parameters that must be established experimentally and are available only for a vertical buoyant jet in a cross flow. It is recommended that an experimental program be carried out to establish the parameters required by the general analysis presented in appendix B.

BIOLOGICAL SCIENCES

In the process of investigating and synthesizing biological data from many sources, it was apparent that knowledge of the offshore marine ecology is still mainly in the observational-descriptive stage. Much remains to be done in basic field research, before accurate predictive techniques will emerge. There is, nevertheless, a wealth of information extant that could be of value to the practicing engineer in minimizing potential hazards to marine life, if the knowledge were in more useful, consistent, and available form:

1. Comprehensive monographs on the ecology of important estuaries and coastal areas should be compiled to describe their abiotic and biota constituents quantitatively in time and space, and define the most important constituents and their interdependencies. Boundaries of the ecological system should also be defined. Where information is lacking, research programs should be sponsored to meet specific needs rather than random interests.
2. Handbooks on biological response of important aquatic organisms to environmental influences (including pollutants) should also be compiled. Although local environmental conditions may vary, coefficients derived under standard conditions should fall within ranges useful for evaluation in mathematical models. A great deal of applied research appears to be necessary in this area to meet current needs.
3. Handbooks on kinds and quantities of wastes discharged to important estuaries or coastal areas should be prepared to assess the cumulative ecological effect.
4. Better mathematical models describing functioning of the aquatic environment should be developed for predictive purposes, including provision for handling biotic aspects.

Since the ecological effects of entrainment of organisms through a power plant's condensers depend on water circulation, the distribution of pelagic organisms in the water proximate to the plant site, and the reproductive rate of the organisms, it appears that in areas of limited water circulation, populations of organisms having low reproductive capacities might be reduced by entrainment. Research is required to establish changes in the quantitative balances between "desirable," and "undesirable" organisms, and what organisms are really "undesirable," since little is known of the interactions among many organisms.

Research is needed on entrainment, to ascertain the relative importance of shear forces, heat, condenser cleaning, anticorrosion materials, and antifouling procedures on marine organisms. More should also be learned of sporadic events such as locally high concentrations of pelagic organisms (e.g., jellyfish), and their effects on power plant operation and the ecological balance.

Section 10
ACKNOWLEDGMENTS

This report was prepared with the assistance of consultants whose interest in the study, critiques of work performed, and substantive contributions are hereby gratefully acknowledged. All of the radionuclide release data for the Forked River Plant and much of the plant description came from Combustion Engineering, Inc., Windsor Locks, Connecticut. Much of the assessment of the effect of radionuclides on man and marine biota was obtained from Dr. William C. Renfro and Dr. Norman H. Cutshall of the Department of Oceanography, Oregon State University, Corvallis, Oregon. Dr. Donald R. F. Harleman of the Hydrodynamics and Water Resources Division of Massachusetts Institute of Technology was most helpful in the thermal diffusion analysis. Mr. C. A. Griscom, environmental consultant of Westerly, R.I., was closely involved in the preparation of certain portions of the physical oceanographic descriptions.

The principal investigators for General Dynamics were:

Thermal diffusion analysis:	Dr. R. F. Robideau
Effects of thermal discharges:	Dr. E. A. Zuraw Mr. D. E. Leone Mr. S. Cohen
Radionuclide release, distribution, and effects:	Mr. R. A. Chapman Mr. E. L. Czapek
Representative site descriptions --	
oceanography:	Mr. M. F. McDonald
biology:	Dr. E. A. Zuraw Mr. D. E. Leone

The study program was managed by Mr. R. W. Marble, and technical direction was provided by Mr. L. V. Mowell. Mr. R. W. Jones organized and controlled preparation of the report, with much of the editing performed by Mr. E. W. Williams and Mr. R. S. Malcolm.

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Appendix A
REDUCTION OF OCEANOGRAPHIC DATA

This appendix presents the method for reducing the oceanographic data for each site to a form appropriate for use in the thermal diffusion analysis. The data will be put in the dimensionless form required by the analysis described in section 5. Advantages of the nondimensional form are twofold: first, either metric or nonmetric units of measure can be used and second, results are applicable to all systems having geometric, thermal, and hydrodynamic similarity. Of course, dimensional results can easily be obtained from the nondimensional results when the normalizing values are given.

As described in the thermal diffusion analysis given in section 5, p 62 ff, the data needed for predicting the thermal field with stratification as to both temperature and density, are two dimensionless functions defined by:

$$T_a = \frac{t_a - t_{ao}}{t_o - t_{ao}} \qquad (1)$$

and

$$P_a = \frac{\rho_{ao} - \rho_a}{\rho_{ao} - \rho_o} \qquad (2)$$

In these equations, t is temperature, ρ is density, while the subscripts, a, o, and ao refer respectively to the condition in the ambient fluid, at the point of discharge, and in the ambient fluid at $Y = 0$. The quantities must be determined as functions of the dimensionless vertical distance $Y = y/D$ where y is measured from the discharge jet center and D is the discarge jet diameter.

In order to carry out the data reduction and thermal diffusion analysis, some characteristics of the power plant and site must be assumed. These values are:

Electrical output	1190 Mw(e)
Heat rejection	7.8×10^9 Btu/hr
Temperature rise across condenser	25^oF
Cooling water flow rate	1355 ft^3/sec
Discharge diameter	15 ft
Ocean depth	250 ft (approximately)

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From the oceanographic data presented in the separate site descriptions, the worst case will be selected for analysis. From a biological point of view, the highest ambient temperature presents the most severe condition and it will be the only temperature used. The corresponding minimum density will also be chosen. Since the assigned ocean depth is 250 ft, the 75-meter data will correspond with data at Y = 0. The reference temperature difference $t_a - t_{ao}$ is 25°F or 13.9°C. The reference density difference $\rho a_o - \rho_a$ is determined, using tables of σ_t*, as follows:

1. The salinity corresponding to the maximum temperature and minimum density will be determined from the tables; e.g., $(\sigma_t)_{ao} = 32.8$ for $t_{ao} = 10.3^{\circ}C$ and $\sigma_t = 25.19$ at the Maine site in the summer.
2. Using the same salinity, a value of σ_t is determined from the tables at a temperature of t_o; e.g., $t_o = 10.3 + 13.9 = 24.7^{\circ}C$ and $(\sigma_t)_o = 21.94^{\circ}C$.
3. The density difference is computed; e.g., $\rho_{ao} - \rho_o = 1.025\ 19 - 1.921\ 94 = 0.00325$.

The dimensionless density can also be defined in terms of σ_t as

$$P_a = \frac{(\sigma_t)_{ao} - (\sigma_t)_a}{(\sigma_t)_{ao} - (\sigma_t)_o}$$

and this form will be used in the actual data reduction. Another quantity required for the analysis is the Froude number, defined as

$$F = \frac{U_o}{\sqrt{Dg\left[\frac{\rho_{ao} - \rho_o}{\rho_o}\right]}}$$

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*Tables of Sigma - t, with Intervals of 0.1, for Temperature and Salinity - by Betty Ann L. Keala. Special Scientific Report - Fisheries No. 506, April 1965. (Sigma - t units are abbreviated expressions for density; e.g., a sigma-t of 26 represents a specific gravity of 1.026 relative to fresh water.)

This quantity can also be written, in terms of the flow rate Q, as

$$F = \frac{4Q}{\pi D^{5/2}\sqrt{g\left[\frac{\rho_{ao} - \rho_o}{\rho_o}\right]}}$$

Using the values of Q and D given above, the Froude number becomes

$$F = \frac{0.349}{\sqrt{\frac{\rho_{ao} - \rho_o}{\rho_o}}}$$

The denominator in this expression changes considerably with site location, primarily because of difference in salinity. The Froude number, therefore, must be computed for each site.

The reduced oceanographic data for the four sites are presented in tables 26 through 29, and the dimensionless temperature and density are plotted in figures 34 through 37. The ocean current data for each site are not presented here because their reduction is unnecessary.

Table 26. Oceanographic Data for the Miami, Florida Site

SUMMER $t_o - t_{ao} = 25^oF = 13.9^oC$, $\rho_{ao} - \rho_o = 4.34(\sigma_t)$, F = 5.35

Y	$t_a(^oC)$	$(t_a - t_{ao})^oC$	T_a	EQUATION	$\rho_a(\sigma_t)$	$(\rho_{ao}-\rho_a)\sigma_t$	P_a	EQUATION
0	24.89	0	0	$T_a = 0.0522Y$	24.42	0	0	$P_a = 0.0575Y$
5.46	28.85	3.96	0.285	$T_a = 0.237 + 0.0087Y$	23.06	1.36	0.314	$P_a = 0.206 + 0.0198Y$
9.84	29.30	4.41	0.317		22.68	1.74	0.401	
12.00	29.65	4.76	0.342	$T_a = 0.342$	22.56	1.86	0.428	$P_a = 0.273 + 0.013Y$
14.20	29.63	4.74	0.342		22.43	1.99	0.458	
16.40	29.70	4.81	0.346		22.31	2.11	0.486	

WINTER $t_o - t_{ao} = 25^oF = 13.9^oC$, $\rho_{ao} - \rho_o = 4.34(\sigma_t)$, F = 5.35

Y	$t_a(^oC)$	$(t_a - t_{ao})^oC$	T_a	EQUATION	$\rho_a(\sigma_t)$	$(\rho_{ao}-\rho_a)\sigma_t$	P_a	EQUATION
0	25.75	0	0	$T_a = 0.00858Y$	24.43	0	0	$P_a = 0.0346Y$
5.46	26.40	0.65	0.0468	$T_a = 0.0468$	23.61	0.82	0.189	$P_a = 0.189$
9.84	26.35	0.60	0.0431	$T_a = -0.0072 + 0.00548Y$	23.62	0.81	0.817	$P_a = 0.134 + 0.00564Y$
12.00	26.46	0.71	0.0510		23.59	0.84	0.194	
14.20	26.65	0.90	0.0648		23.53	0.90	0.208	
16.40	26.90	1.15	0.0828		23.45	0.98	0.226	

Table 27. Oceanographic Data for the Wiscasset, Maine Site

SUMMER $t_o - t_{ao} = 25^oF = 13.9^oC$, $\rho_{ao} - \rho_o = 3.25(\sigma_t)$, F = 6.18

Y	$t_a(^oC)$	$(t_a - t_{ao})^oC$	T_a	EQUATION	$\rho_a(\sigma_t)$	$(\rho_{ao}-\rho_a)\sigma_t$	P_a	EQUATION
0	10.27	0	0	$T_a = 0.0195Y$	25.19	0	0	$P_a = 0.0135Y$
5.46	11.75	1.48	0.106		24.95	0.24	0.074	$P_a = 0.345 + 0.078Y$
9.84	12.93	2.66	0.191	$T_a = 0.60 + 0.08Y$	23.86	1.33	0.409	
12.00	15.00	4.73	0.340		23.37	1.82	0.560	
14.20	17.77	7.50	0.540	$T_a = 0.069 + 0.033Y$	22.71	2.48	0.763	$P_a = 0.33 + 0.0305Y$
16.40	18.80	8.53	0.613		22.49	2.70	0.830	

WINTER* $t_o - t_{ao} = 25^oF = 13.9^oC$, $\rho_{ao} - \rho_o = 2.97(\sigma_t)$, F = 6.48

Y	$t_a(^oC)$	$(t_a - t_{ao})^oC$	T_a	EQUATION	$\rho_a(\sigma_t)$	$(\rho_{ao}-\rho_a)\sigma_t$	P_a	EQUATION
0	8.45	0		$T_a = 0$	25.64	0		$P_a = 0$
5.46	8.48	0.03			25.30	0.34		
9.84	8.84	0.39			25.11	0.53		
12.00	8.86	0.48			25.08	0.56		
14.20	8.68	0.23			25.12	0.52		
16.40	8.33	-0.12			25.12	0.52		

*Because variations in temperature and density are not within the accuracy of the data, these quantities are assumed to be constant.

Table 28. Oceanographic Data for the Sea Girt, New Jersey Site

SUMMER $t_o - t_{ao} = 25^oF = 13.9^oC$, $\rho_{ao} - \rho_o = 3.32(\sigma_t)$, F = 6.12

Y	$t_a(^oC)$	$(t_a - t_{ao})^oC$	T_a	EQUATION	$\rho_a(\sigma_t)$	$(\rho_{ao}-\rho_a)\sigma_t$	P_a	EQUATION
0	11.0	0	0	$T_a = 0.0066Y$	24.9	0	0	
5.46	11.5	0.5	0.036		24.9	0	0	$P_a = 0.1225Y$
9.84	15.5	4.5	0.324	$T_a = -0.535 + 0.1045Y$	24.5	0.4	0.1205	
12.00	21.0	10.0	0.720		22.0	2.9	0.87	$P_a = -2.44 + 0.26Y$
14.20	23.0	12.0	0.864	$T_a = 0.135 + 0.0488Y$	21.3	3.6	1.255	$P_a = 1.255$
16.40	24.0	13.0	0.935		21.3	3.6	1.255	

WINTER* $t_o - t_{ao} = 25^oF = 13.9^oC$, $\rho_{ao} - \rho_o = 3.27(\sigma_t)$, F =6.17

Y	$t_a(^oC)$	$(t_a - t_{ao})^oC$	T_a	EQUATION	$\rho_a(\sigma_t)$	$(\rho_{ao}-\rho_a)\sigma_t$	P_a	EQUATION
0	10.7	0		$T_a = 0$	26.0	0		$P_a = 0$
5.46	10.6	-0.1			25.9	0.1		
9.84	10.5	-0.2			25.8	0.2		
12.00	10.2	-0.5			25.8	0.2		
14.20	9.8	-0.9			25.7	0.3		
16.40	9.5	-1.2			25.7	0.3		

*Because variations in temperature and density are not within the accuracy of the data, the quantities are assumed to be constant.

Table 29. Oceanographic Data for the San Onofre, California Site

SUMMER $t_o - t_{ao} = 25^{o}F = 13.9^{o}C$, $\rho_{ao} - \rho_o = 3.77(\sigma_t)$, $F = 5.74$

Y	$t_a(^{o}C)$	$(t_a - t_{ao})^{o}C$	T_a	EQUATION	$\rho_a(\sigma_t)$	$(\rho_{ao}-\rho_a)\sigma_t$	P_a	EQUATION
0	14.35	0	0	$T_a = 0.0226Y$	24.98	0	0	$P_a = 0.017Y$
5.46	15.80	1.45	0.104		24.64	0.34	0.0902	
9.84	17.06	2.71	0.195		24.35	0.63	0.167	$P_a = -0.512 + 0.069Y$
12.00	18.12	3.77	0.271	$T_a = -1.079 + 0.1125Y$	23.92	1.06	0.282	
14.20	22.50	8.15	0.586		23.22	1.76	0.467	$P_a = 0.468$
16.40	25.00	10.65	0.766		23.21	1.77	0.469	

WINTER $t_o - t_{ao} = 25^{o}F = 13.9^{o}C$, $\rho_{ao} - \rho_o = 3.94(\sigma_t)$, $F = 5.62$

Y	$t_a(^{o}C)$	$(t_a - t_{ao})^{o}C$	T_a	EQUATION	$\rho_a(\sigma_t)$	$(\rho_{ao}-\rho_a)\sigma_t$	P_a	EQUATION
0	15.98	0	0	$T_a = 0.00806Y$	24.75	0	0	$P_a = 0.0242Y$
5.46	16.59	0.61	0.044	$T_a = -0.117 + 0.0294Y$	24.28	0.47	0.119	
9.84	18.38	2.40	0.173	$T_a = 0.104 + 0.007Y$	23.81	0.94	0.238	$P_a = .0172 + 0.0067Y$
12.00	18.60	2.62	0.188		23.75	1.00	0.254	
14.20	18.64	2.66	0.191		23.73	1.02	0.259	
16.40	19.02	3.04	0.219		23.64	1.11	0.282	

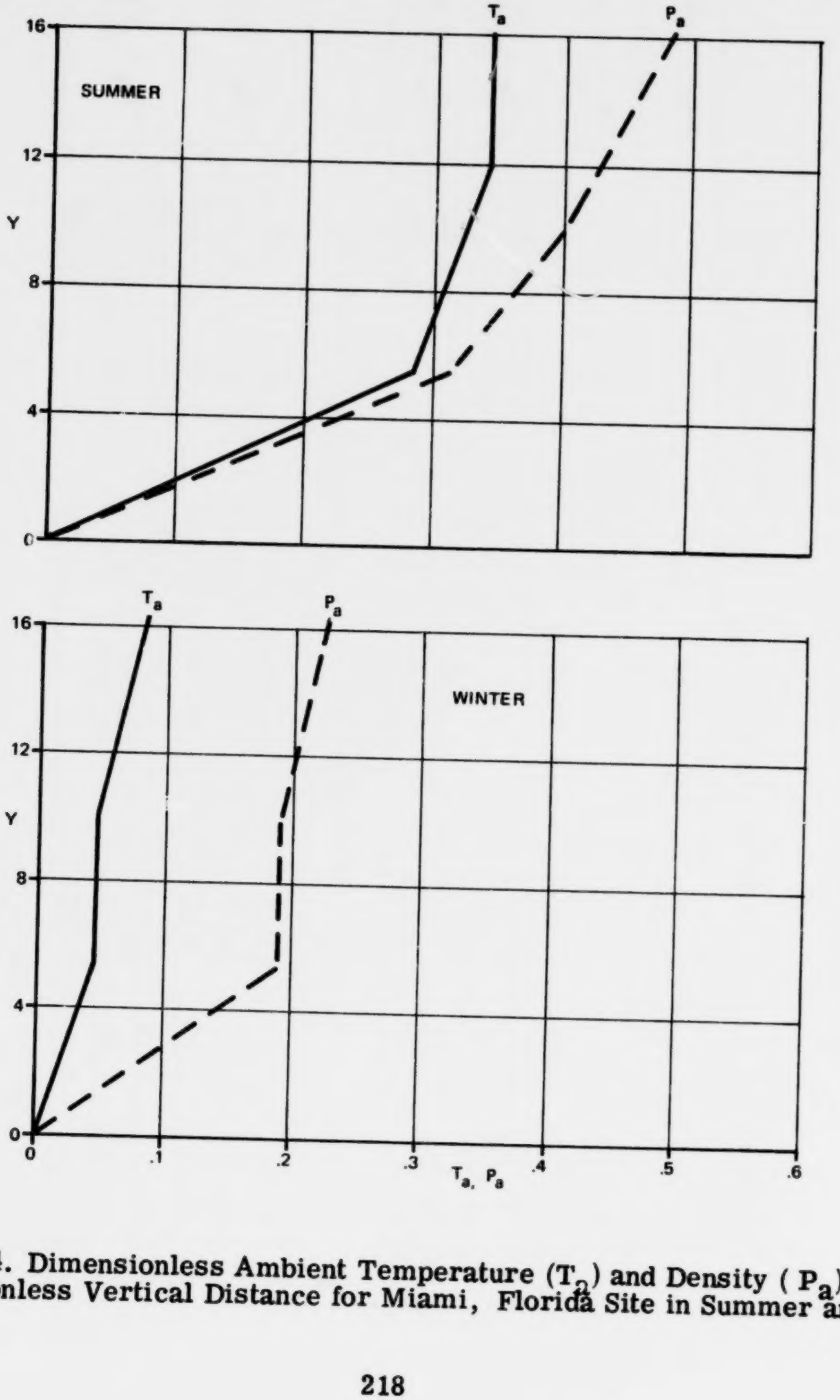

Figure 34. Dimensionless Ambient Temperature (T_a) and Density (P_a) vs Dimensionless Vertical Distance for Miami, Florida Site in Summer and Winter

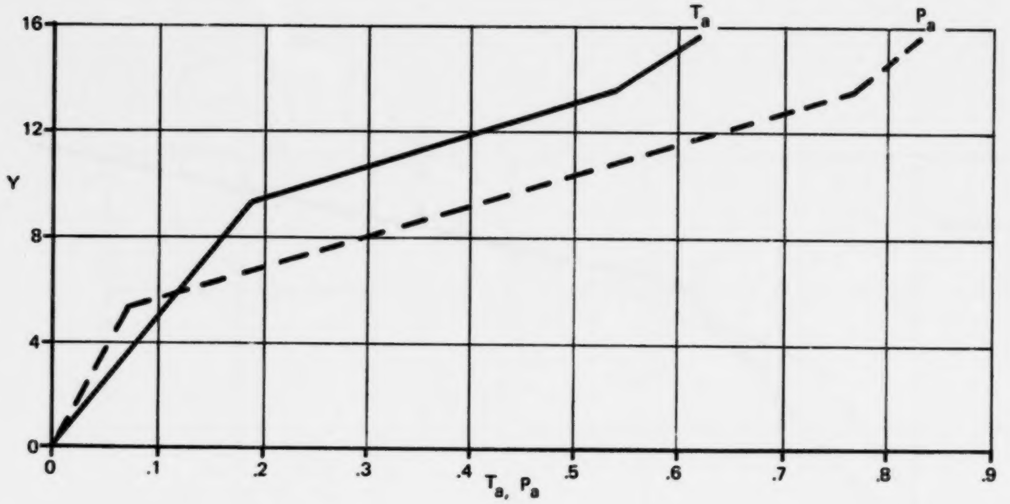

Figure 35. Dimensionless Ambient Temperature (T_a) and Density (P_a) vs Dimensionless Vertical Distance for Wiscasset, Maine Site in Summer.

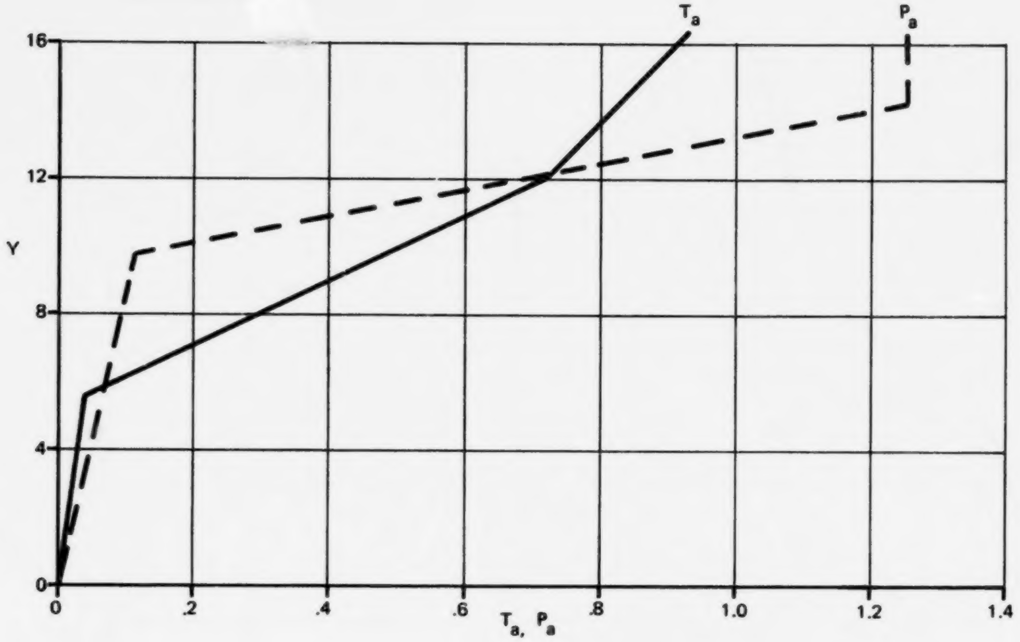

Figure 36. Dimensionless Ambient Temperature (T_a) and Density (P_a) vs Dimensionless Vertical Distance for Sea Girt, New Jersey Site in Summer

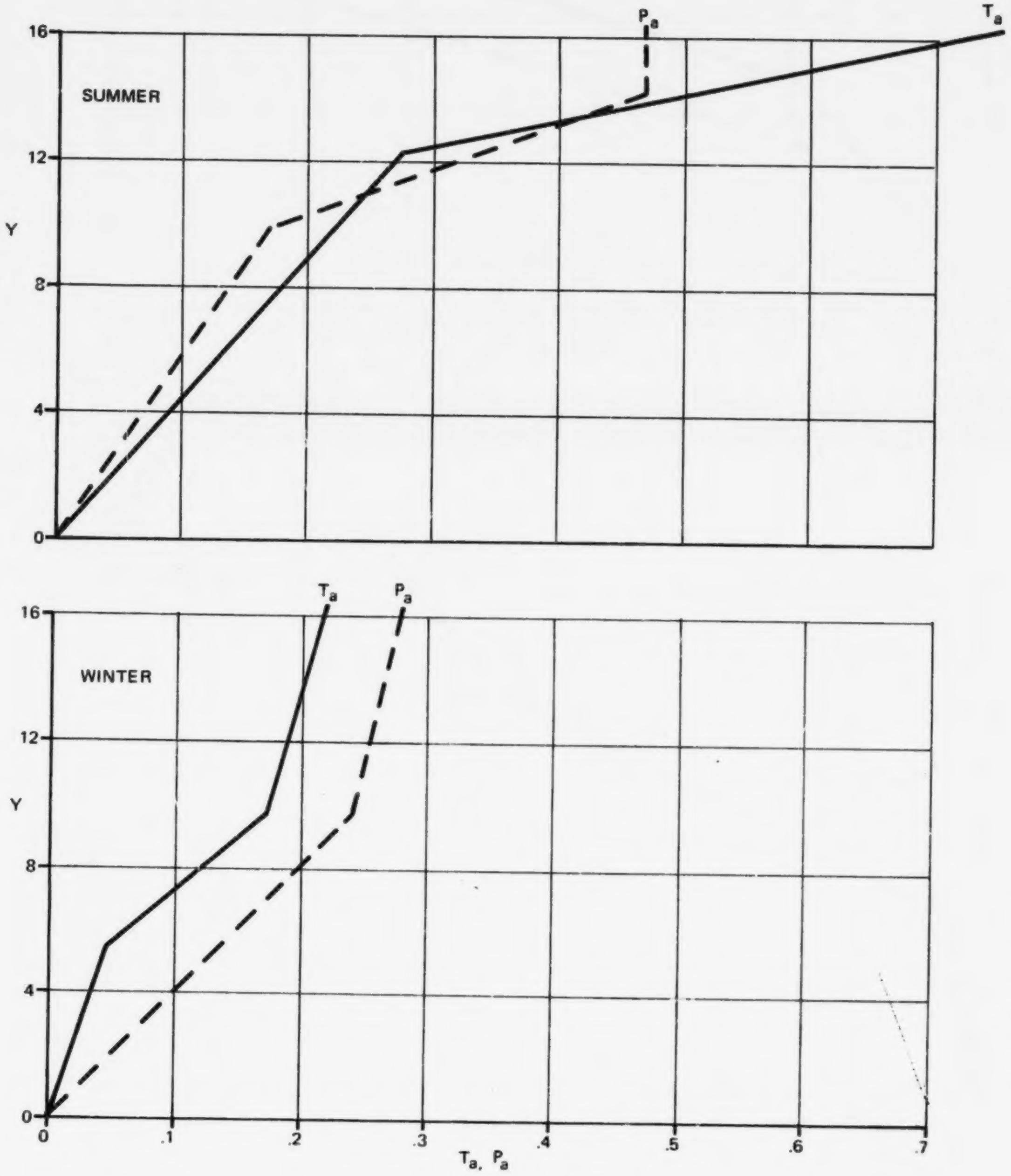

Figure 37. Dimensionless Ambient Temperature (T_a) and Density (P_a) vs Dimensionless Vertical Distance for San Onofre, California Site in Summer and Winter.

Appendix B

THEORETICAL ANALYSIS OF A ROUND HORIZONTAL BUOYANT JET IN A GENERAL STREAM OF HOMOGENEOUS DENSITY

Introduction

This note presents a theoretical analysis of the behavior of a round, buoyant jet, ejected horizontally into an infinite body of fluid that has a homogeneous density and a current with all three velocity components. The technique employed follows that of Fan* who considered a round, vertical buoyant jet being ejected into a cross stream.

Analysis

As shown by figure 38, the jet emerges with an initial diameter D, uniform velocity u_o, and density ρ_o. The jet centerline describes a path s, in space, and at point E on the path, the jet flow is fully established. At a general point P, the unit vector $\overline{T}$, which is tangent to the centerline, has an elevation angle β, and an azimuth angle φ. The velocity of the jet on the centerline is u_j and is coincident with $\overline{T}$. The ambient fluid has homogeneous density ρ_a, and three components of velocity, u_x, u_y, u_z. The components comprise a velocity vector $\bar{u}_a$, such that:

$$\bar{u}_a = u_x\ \hat{i} + u_y\ \hat{j} + u_z\ \hat{k}$$

and

$$\left|\bar{u}_a\right| = \left(u_x{}^2 + u_y{}^2 + u_z{}^2\right)^{\frac{1}{2}}$$

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*Fan, L. N., "Turbulent Buoyant Jets into Stratified or Flowing Ambient Fluids," Report KH-R-15, W. M. Keck Laboratory of Hydraulics and Water Resources, California Institute of Technology, 1967.

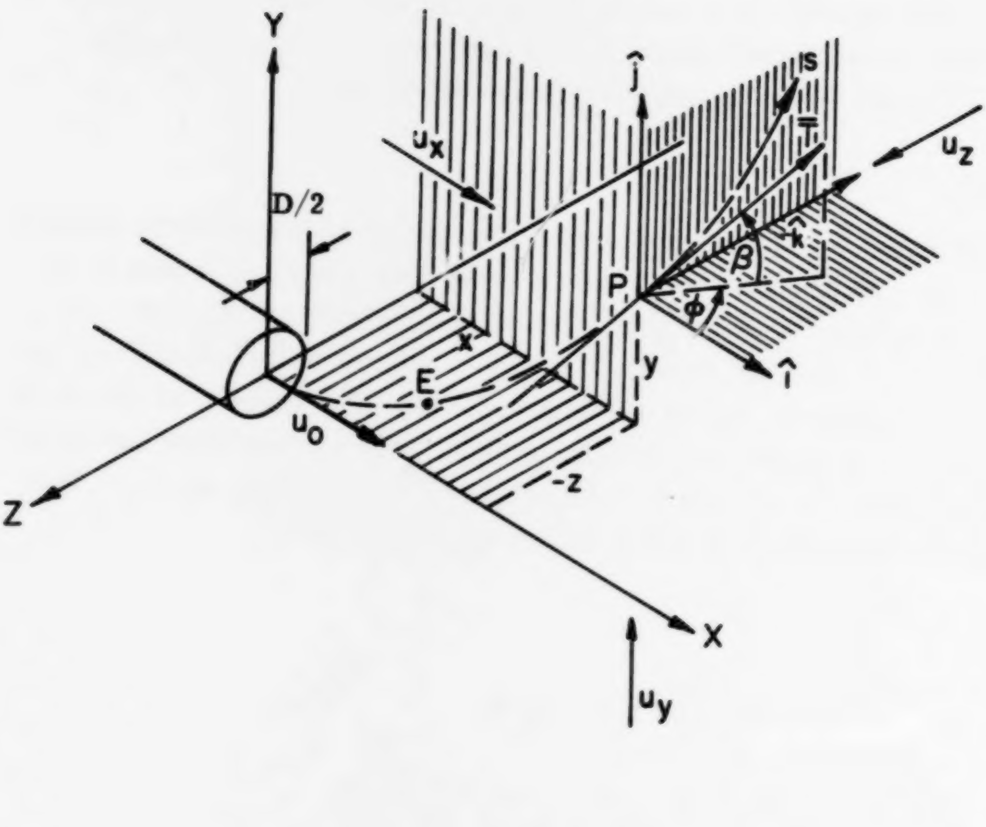

Figure 38. Schematic Diagram of the Jet

The vectors, $\bar{u}_a$ and $\bar{T}$, are separated by an angle, θ , as shown by figure 39. The projection of $\bar{u}_a$ parallel to $\bar{T}$ is $\bar{u}_a \cos\theta$. The magnitude of the jet velocity along the centerline is, therefore,

$$\left|\bar{u}_j\right| = \left|\bar{u}_a\right| \cos\theta + u$$

where u is the excess over the ambient velocity component.

The assumptions in this analysis are:

1. The jet and ambient consist of the same incompressible fluid.
2. The jet and ambient densities differ by virtue of temperature difference alone.
3. The Boussinesq assumption applies.
4. The jet fluid density is a linear function of temperature.
5. The jet is turbulent with no Reynolds number dependence.
6. The curvature of the jet's path is sufficiently small so that any effect of such curvature may be neglected.
7. The jet retains axial symmetry, and the velocity profile is Gaussian above the component of ambient velocity in the direction parallel to the jet. That is:

   $$u^*(r, s) = \left|\bar{u}_a\right| \cos\theta + u(s)\, e^{-(r/b)^2} \tag{1}$$

   where r is a radial coordinate normal to the jet centerline, and b is a local characteristic jet radius which depends on s in a manner to be determined from the analysis. The angle θ is also a function of s; thus the analysis applies only to the zone of established flow, where all profiles are fully developed.
8. The density profile is also Gaussian.

$$\rho_a - \rho^*(r, s) = \left[\rho_a - \rho(s)\right] e^{-(r/b)^2} \tag{2}$$

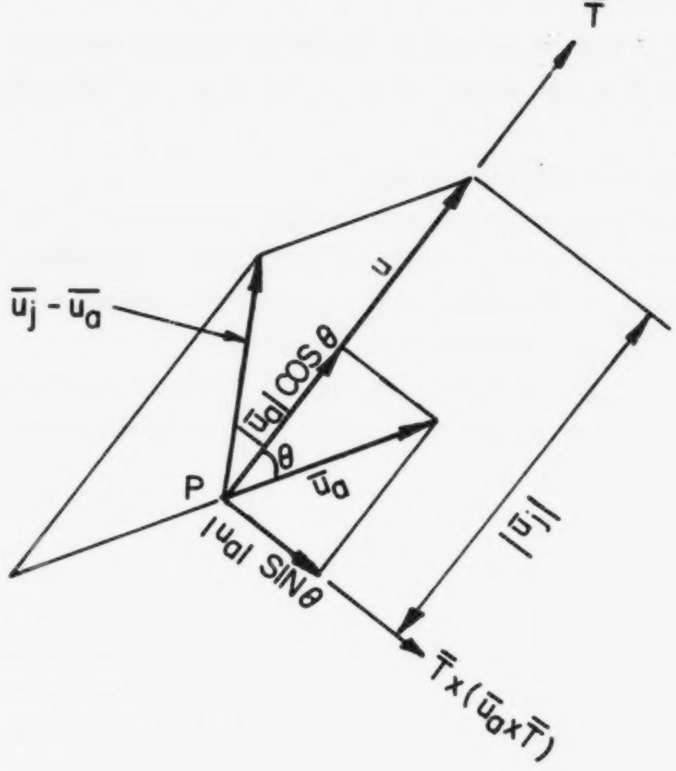

Figure 39. Velocities in the $\bar{T}$, $\overline{u_a}$ Plane

9. The jet entrainment relationship is represented by the equation:

$$\frac{dQ}{ds} = 2\pi\alpha \; b \left|\bar{u}_j - \bar{u}_a\right| \tag{3}$$

where α is the entrainment coefficient and $\left|\bar{u}_j - \bar{u}_a\right|$ is the magnitude of the vector difference of the two velocities.

10. The effect of the pressure field can be lumped into a gross drag term, proportional to the square of the velocity component of the oncoming stream normal to the jet axis.

11. Schmidt number equals unity.

Continuity. The continuity equation, based upon the assumed entrainment mechanism, can be expressed:

$$\frac{dQ}{ds} = \frac{d}{ds}\int_A u^* \, dA = 2\pi\alpha \; b \left|\bar{u}_j - \bar{u}_a\right|$$

$$= 2\pi\alpha \, b \left(\left|\bar{u}_a\right|^2 \sin^2\theta + u^2 \right)^{\frac{1}{2}} \tag{4}$$

The integral can be evaluated from the assumed velocity profile as follows:

$$\int_A u^* \, d\,A = 2\pi \int_0^{b\sqrt{2}} \left(\left|\bar{u}_a\right| \cos\theta + u\, e^{-(r/b)^2} \right) r\,d\,r$$

which may be approximated by:

$$\int_A u^* \, d\,A = 2\pi \left\{ \left|\bar{u}_a\right| \cos\theta \int_0^{b\sqrt{2}} r\,d\,r + u \int_0^{\infty} r e^{-(r/b)^2} dr \right\}$$

$$= \pi b^2 \left(2 \left|\bar{u}_a\right| \cos\theta + u\right) \tag{5}$$

The continuity equation may be written then in the form:

$$\frac{d}{ds}\left\{b^2\left(2\left|\bar{u}_a\right|\cos\theta+u\right)\right\} = 2\alpha b\left(\left|\bar{u}_a\right|^2\sin^2\theta+u^2\right)^{\frac{1}{2}} \tag{6}$$

Momentum. The momentum equations, one for each direction, can be written in integral form utilizing the drag on an infinitesimal element, ds, apportioned to the respective directions.

x Direction. The change of jet momentum rate in the x direction, in a distance ds, is equal to the momentum rate, in the same direction, of the entrained ambient fluid plus the x component of drag force.

$$\frac{d}{ds}\int_A \rho^* u^* \left(u^*\cos\beta\cos\phi\right) dA =$$

$$= \rho_a 2\pi b\ \alpha u_x \left(\left|\bar{u}_a\right|^2\sin^2\theta+u^2\right)^{\frac{1}{2}} + (F_d)_x \tag{7}$$

where $(F_d)_x$ is the x component of total drag per unit length which will be formulated in a further section of this note. Performing the necessary integrations:

$$\frac{d}{ds}\left(\frac{\pi}{2}\ \rho_a b^2\cos\beta\cos\phi\left\{2\left|u_a\right|\cos\theta+u\right\}^2\right) =$$

$$= 2\pi\ \rho_a\,\alpha b u_x\ \left(\left|\bar{u}_a\right|^2\sin^2\theta+u^2\right)^{\frac{1}{2}} + (F_d)_x \tag{8}$$

y Direction. The change of jet momentum rate in the y direction, in a distance ds, is equal to the momentum rate, in the same direction, of the entrained ambient fluid, the y component of drag force, and the buoyancy force.

$$\frac{d}{ds}\int_A \rho^* u^* \left(u^*\sin\beta\right) dA = 2\pi\ \rho_a\alpha b u_y\ \left(\left|\bar{u}_a\right|^2\sin^2\theta+u^2\right)^{\frac{1}{2}} +$$

$$+ (F_d)_y + \int_A g\left(\rho_a-\rho^*\right) dA \tag{9}$$

Performing the integrations:

$$\frac{d}{ds}\left\{\frac{\pi}{2}\ \rho_a b^2 \sin\beta \left(2\ |\bar{u}_a| \cos\theta + u\right)^2\right\} =$$

$$= 2\pi\ \rho_a \alpha b u_y \left(|\bar{u}_a|^2 \sin^2\theta + u^2\right)^{\frac{1}{2}} + (F_d)_y +$$

$$+\ \pi b^2 g\ (\rho_a - \rho) \qquad (10)$$

z-Direction. Momentum in the z direction is formulated similarly to that in the x direction. Formulating it, the result may be written:

$$\frac{d}{ds}\left\{\frac{\pi}{2}\ \rho_a b^2 \cos\beta \sin\phi \left(2\ |\bar{u}_a| \cos\theta + u\right)^2\right\} =$$

$$= 2\pi\ \rho_a \alpha b u_z \left(|\bar{u}_a|^2 \sin^2\theta + u^2\right)^{\frac{1}{2}} + (F_d)_z \qquad (11)$$

Conservation of Density. The density flux is conserved since the ambient fluid is homogeneous. Thus:

$$\frac{d}{ds}\int_A u^* \left(\rho_a - \rho^*\right)\, dA = 0 \qquad (12)$$

After evaluating the integral:

$$\frac{d}{ds}\left\{b^2 \left(2\ |\bar{u}_a| \cos\theta + u\right) \left(\rho_a - \rho\right)\right\} = 0 \qquad (13)$$

Geometry. It can be found from figure 38 that:

$$dx = \cos\beta \cos\phi\, ds \qquad (14)$$

$$dy = \sin\beta ds \qquad (15)$$

$$dz = \cos\beta \sin\phi ds \qquad (16)$$

Accordingly, $\bar{T} = \cos\beta \cos\phi\, \hat{i} + \sin\beta\, \hat{j} + \cos\beta \sin\phi\, \hat{k}$. The angle θ can be found from a dot product of vectors $\bar{u}_a$ and $\bar{T}$ as follows:

$$\cos\theta = \frac{\bar{u}_a \cdot \bar{T}}{|\bar{u}_a|\,|\bar{T}|} = \frac{u_x}{|\bar{u}_a|} \cos\beta \cos\phi + \frac{u_y}{|\bar{u}_a|} \sin\beta + \frac{u_z}{|\bar{u}_a|} \cos\beta \sin\phi \qquad (17)$$

Drag Force. The drag force on an infinitesimal length of the jet is a vector whose magnitude is assumed to be:

$$|\bar{F}_d| = C_d \frac{\rho_a |\bar{u}_a|^2 \sin^2\theta}{2} \sqrt{2}b \qquad (18)$$

The direction of the drag force is normal to $\bar{T}$. Since components of the drag force in the cartesian directions are required, it is necessary to determine the drag force direction cosines. This is done by evaluating the triple product $\bar{T} \times (\bar{u}_a \times \bar{T})$, giving a vector normal to $\bar{T}$.

$$\begin{aligned} \bar{T} \times (\bar{u}_a \times \bar{T}) = & \left\{ u_x(1-\cos^2\beta \cos^2\phi) - u_y \cos\beta \sin\beta \cos\phi - u_z \cos^2\beta \cos\phi \sin\phi \right\} \hat{i} + \\ & + \left\{ u_y(1 - \sin^2\beta) - u_x \cos\beta \sin\beta \cos\phi - u_z \cos\beta \sin\beta \sin\phi \right\} \hat{j} + \\ & + \left\{ u_z(1 - \cos^2\beta \sin^2\phi) - u_x \cos^2\beta \cos\phi \sin\phi - u_y \cos\beta \sin\beta \sin\phi \right\} \hat{k} \end{aligned} \qquad (19)$$

Defining, for convenience,

$$\bar{T} \times (\bar{u}_a \times \bar{T}) = A_d \hat{i} + B_d \hat{j} + E_d \hat{k}$$

The force components may be written:

$$(F_d)_x = \frac{A_d}{(A_d^{\,2} + B_d^{\,2} + E_d^{\,2})^{\frac{1}{2}}} \quad |\overline{F}_d| \tag{20}$$

$$(F_d)_y = \frac{B_d}{(A_d^{\,2} + B_d^{\,2} + E_d^{\,2})^{\frac{1}{2}}} \quad |\overline{F}_d| \tag{21}$$

$$(F_d)_z = \frac{E_d}{(A_d^{\,2} + B_d^{\,2} + E_d^{\,2})^{\frac{1}{2}}} \quad |\overline{F}_d| \tag{22}$$

Initial Conditions. The initial conditions taken at the beginning of the zone of established flow, point E, are:

$$\begin{array}{lll} u(e) = u_e & \theta(e) = \theta_e & x(e) = x_e \\ b(e) = b_e & \beta(e) = \beta_e & y(e) = y_e \\ \rho(e) = \rho_e & \phi(e) = \phi_e & z(e) = z_e \end{array}$$

All equations require integration from these values except the conservation of density, equation (13). This can be expressed as:

$$b^2 (2 \, |\bar{u}_a| \cos\theta + u) \, (\rho_a - \rho) = b_e^2 (2 \, |\bar{u}_a| \cos\theta_e + u_e) \, (\rho_a - \rho_e) = \text{constant} \tag{23}$$

Normalized Equations and Dimensionless Parameters. The set of equations can be normalized by defining dimensionless parameters as follows:

velocities:

$U = u/u_o$ $\qquad U_y = u_y/u_o$

$U_x = u_x/u_o$ $\qquad U_z = u_z/u_o$

dilution:

$$\frac{\rho_a - \rho}{\rho_a - \rho_o} = \rho'$$

Froude number:

$$F = \frac{u_o}{\sqrt{Dg\left(\frac{\rho_a - \rho_o}{\rho_o}\right)}}$$

geometry:

$X = x/D$ $\qquad S = s/D$

$Y = y/D$ $\qquad B = 2\sqrt{2}\, b/D$

$Z = z/D$

In addition, a few nondimensional terms are defined as follows:

$$U_j = 2\left|U_a\right| \cos\theta + U$$

$$U_n = \left|U_a\right| \sin\theta$$

Equations (6), (8), (10), (11), (13) may be restated in terms of the nondimensional parameters as:

$$\frac{d}{ds}\left(B^2 U_j\right) = \frac{8}{\sqrt{2}} \alpha B \left(U_n^2 + U^2\right)^{\frac{1}{2}} \tag{24}$$

$$\frac{d}{ds}\left\{B^2 U_j^2 \cos\beta \cos\phi\right\} = \frac{16}{\sqrt{2}} \alpha B U_x \left\{U_n^2 + U^2\right\}^{\frac{1}{2}} + \left(F'_d\right)_x \tag{25}$$

$$\frac{d}{ds}\left\{B^2 U_j^2 \cos\beta \sin\phi\right\} = \frac{16}{\sqrt{2}} \alpha B U_z \left\{U_n^2 + U^2\right\}^{\frac{1}{2}} + \left(F'_d\right)_z \tag{26}$$

$$\frac{d}{ds}\left\{B^2 U_j^2 \sin\beta\right\} = \frac{16}{\sqrt{2}} \alpha B U_y \left\{U_n^2 + U^2\right\}^{\frac{1}{2}} + \frac{2B^2}{F^2}\rho' + \left(F'_d\right)_y \tag{27}$$

$$B^2 U_j \rho' = B_e^2 \left(U_j\right)_e \rho'_e \tag{28}$$

The primed drag force terms are the indicated components of the dimensionless drag force obtained from equation (18):

$$\left|\overline{F}'_d\right| = \frac{4}{\pi} C_d B U_n^2 \tag{29}$$

Method of Solution. Solutions to equations (24) through (27) may be obtained by any convenient method of numerical integration. Although the dependent variables, B, U, θ, β, and ϕ do not appear as sole arguments of a derivative, they may still be determined by algebraic solution of actual derivative arguments.

Discussion

The preceding formulation is achieved by extension of the analysis in the reference on page 221. The computation of any intended condition may be made using the developed equations, but input data such as drag coefficient and entrainment data, to suit, must be available before the condition may be computed with confidence. A few drag and entrainment data are available (these also appear in the reference), but do not cover the complete range of conditions that the formulation can handle now. Considerably more experimental data are needed before the generality of the formulation can be used with confidence.

One limitation of the formulation as it presently exists is constant drag and entrainment coefficient. The quantities realistically vary with the angle of incidence, θ. To include this effect is an easy extension of the formulation, but again, drag and entrainment data must be available to obtain reliable results.

Another limitation is homogeneous stream velocity. Realistically, stream velocity is a function of space, (x, y, z). This effect may also be easily accommodated, if desired.

Results

A sample problem, that of a horizontal current in the plane of a jet, is analyzed to indicate the potential capability of the analysis. The results are shown by figure 40.

This particular problem is chosen because the path of the jet is in a vertical plane and thus the results can be clearly presented. Two extreme cases are computed; where the current and the jet discharge are in the same direction, and where they are opposed.

The entrainment of the ambient fluid is proportional to the velocity difference between the jet and the current. In the first case, where the direction of flow is the same, the entrainment and the consequent dilution are less than if there were no ambient flow. This decrease in dilution is offset to some degree by the tendency of the current to extend the path of the jet horizontally. In the second case, with the current opposing the jet, and assuming that the condenser intake and outlet are also in opposite directions, a worst case is presented for the recirculation of part of the discharge water.

The jet centerline paths with a one-knot current both following and opposing the discharge jet are shown by figure 3, along with the case of no current. A Froude number of five is used for the calculation which gives a ratio of current velocity to jet velocity of 0.261. Drag coefficient and entrainment coefficient are chosen $C_d = 0.1$ and $\alpha = 0.082$, respectively.

Points of common centerline temperature are also indicated for $\gamma = 0.2$ and 0.4,

where

$$\gamma = \frac{t - t_a}{t_o - t_a}$$

and t = local temperature
t_a = ambient temperature
t_o = discharge temperature

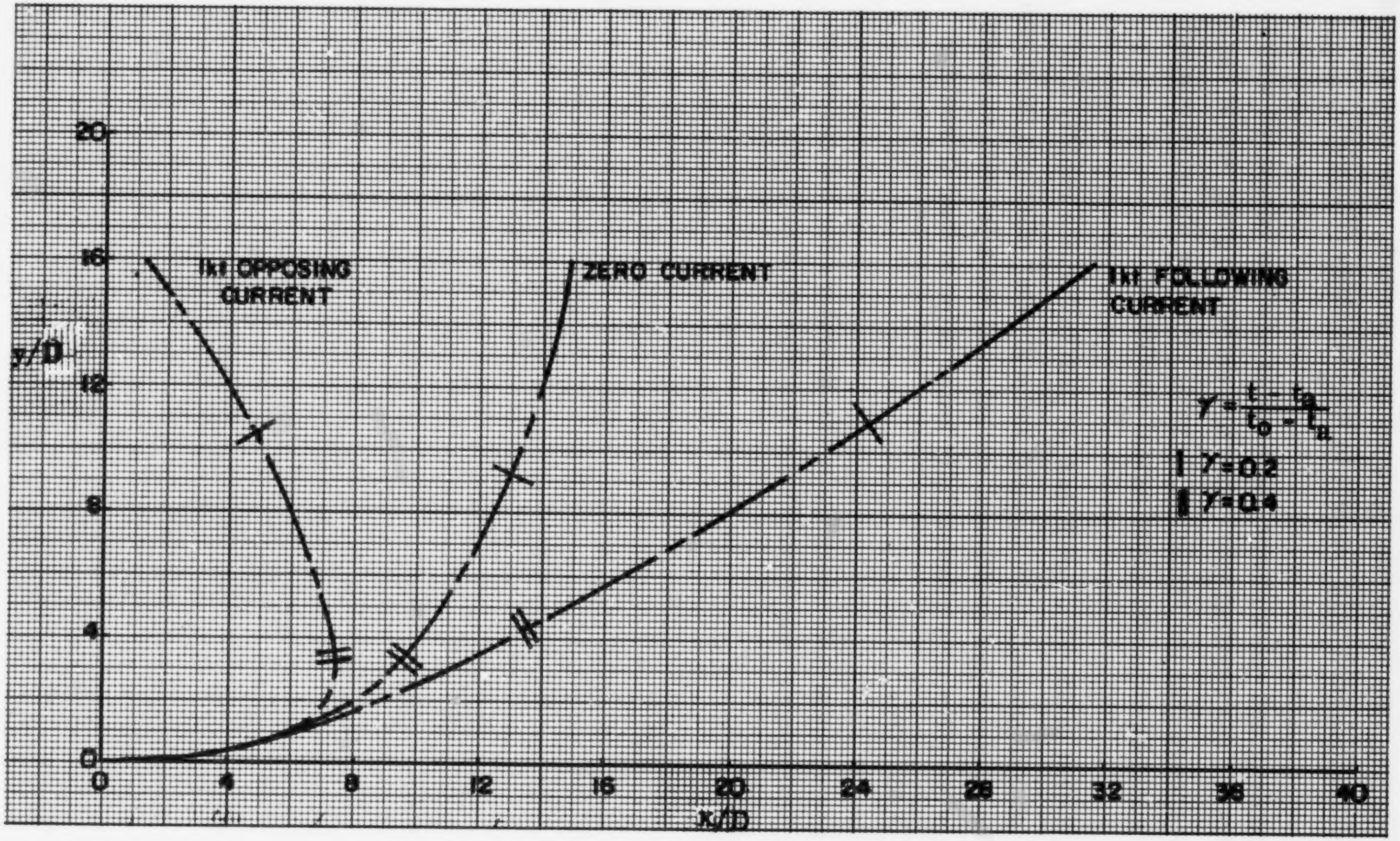

Figure 40. Centerline Path of a Horizontal Buoyant Jet Discharging into an Infinite Fluid of Homogeneous Density with Various Current Conditions. F = 5.0.

For the sake of clarity, the isotherms have not been plotted. The coordinates have been nondimensionalized with respect to the discharge diameter.

The values of the drag and entrainment coefficients are low compared with those used by Fan for the vertical jet. They are chosen to give "worst case" results and thus ensure that the predicted thermal effect on the environment is greater than would be expected under actual conditions.

A low drag coefficient produces a predicted jet path that rises rapidly and therefore has a correspondingly low dilution and a greater effect on the ocean surface. The low entrainment coefficient is that used for a jet with no ambient current, thus the jet incurs substantially lower dilution than it would in the presence of a current.

There are no experimental data available in the literature for the cases considered here, and it must be emphasized that the significance of the results is mainly qualitative.

NOMENCLATURE

English Symbols

$A =$ jet cross-sectional area normal to the jet axis (ft^2)

$B = 2\sqrt{2}b/D$ dimensionless local characteristic radius

$b =$ local characteristic jet radius (ft)

$C_d =$ dimensionless drag coefficient based on projected area

$D =$ discharge jet diameter (ft)

$F = u_o \Big/ \sqrt{\dfrac{g(\rho_a - \rho_o)D}{\rho_o}}$ densimetric Froude number

$|F'_d| =$ dimensionless total drag force per unit length

$|\bar{F}_d| =$ total drag force per unit length (lb/ft)

$\left.\begin{matrix}(F_d)_x \\ (F_d)_y \\ (F_d)_z\end{matrix}\right\} =$ components of drag force per unit length (lb/ft)

$g =$ gravitational acceleration (ft/sec^2)

$\hat{i}, \hat{j}, \hat{k} =$ unit vectors in the x, y, z directions, respectively

$Q =$ jet flow rate (ft^3/sec)

$r =$ radial distance from jet centerline (ft)

$S = s/D$ dimensionless distance along the jet centerline

$s =$ distance along jet centerline (ft)

$t =$ temperature (^oF)

$U = u/u_o$ dimensionless velocity ratio

$\left.\begin{matrix}U_x \\ U_y \\ U_z\end{matrix}\right\} =$ dimensionless components of ambient velocity

$u =$ jet velocity along the centerline in excess of the ambient velocity component (ft/sec)

$\bar{u}_a$ = ambient velocity (ft/sec)
$\bar{u}_j$ = jet velocity along the centerline (ft/sec)
$\left.\begin{matrix} u_x \\ u_y \\ u_z \end{matrix}\right\}$ = components of ambient velocity (ft/sec)
$X = x/D$ dimensionless horizontal coordinate
x = horizontal coordinate (ft)
$Y = y/D$ dimensionless vertical coordinate
y = vertical coordinate (ft)
$Z = z/D$ dimensionless transverse coordinate
z = transverse coordinate (ft)

Greek Symbols

α = dimensionless entrainment coefficient
β = elevation angle of jet (radians)
$\gamma = \frac{t - t_a}{t_o - t_a}$ dimensionless temperature
θ = angle between tangent to the jet and ambient velocity (radians)
ρ = water density ($lb\text{-}sec^2/ft^4$)
$\rho' = \frac{\rho_a - \rho}{\rho_a - \rho_o}$ dimensionless density
ϕ = azimuth angle of jet (radians)

Subscripts

a = condition in the ambient fluid

e = beginning of the zone of established flow

o = condition at the point of discharge

Superscript

$*$ = a function of s and r

Appendix C

DERIVATION OF DOWNSTREAM RADIONUCLIDE CONCENTRATIONS WITH RADIOACTIVE DECAY CHAINS OF ONE, TWO, AND THREE RADIONUCLIDES

The formula for the concentration of a nuclide having negligible decay and being released continuously is:

$$\phi(x,y) = \frac{Q}{\sqrt{2\pi}\ DU_o cx} e^{-\frac{y^2}{2c^2x^2}}$$

where:

$\phi(x,y)$ = radionuclide concentration in the sea (μ Ci/cc)
Q = release rate of radionuclides (Curies/yr)
D = depth of water
U_o = velocity of current past the site
x = downstream coordinate
y = cross current coordinate
c = constant

The formula for the concentration of a nuclide having negligible decay and being instantaneously released is:

$$\phi(x,r) = \frac{Q}{2\pi\ D\ c^2x^2} e^{-\frac{r^2}{2c^2x^2}}$$

where all quantities are the same as continuous release except Q = quantity of radionuclides released (Curies).

The derivation of these two formulas can be found in the descriptions of theory: normal operation, downstream plume; and nuclear accidental release in the section on radionuclide distribution in the sea (section 7, p 149 ff).

The effect of decay will be derived here for the case of continuous release, but because of the similarity of the formulas will be applicable to batch release. The centerline atom density in sea water plotted against downstream distance is shown as the zero decay curve in the graph below:

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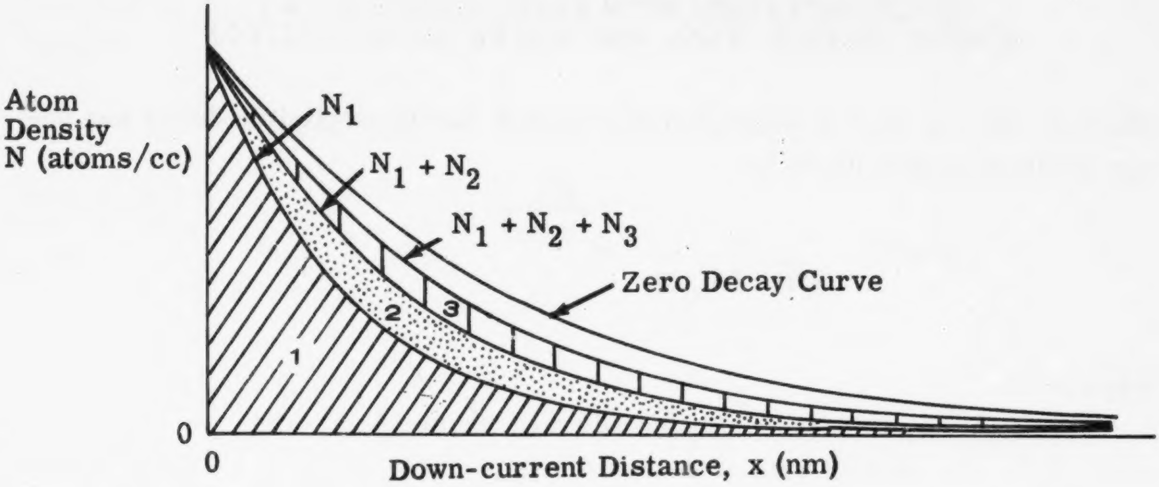


A single radionuclide being released and decaying will have an atom density, N_1, less than the zero decay curve, shown typically as shaded portion 1 of the graph. If the first radionuclide decays to a second radionuclide, the typical atom density of the second radionuclide is shown as stipled portion 2 of the graph. Note that the sum of the atom densities of the first and second radionuclides, $N_1 + N_2$, cannot exceed the zero decay curve because of conservation of radionuclides. If the second radionuclide decays to a third radionuclide, the atom density of the third radionuclide is typically shown as portion 3 of the graph. Again, the sum of the atom densities of the first, second, and third radionuclides, $N_1 + N_2 + N_3$, cannot exceed the zero decay curve.

Assume the two causes of reduction of radionuclide concentration (dilution and decay) to be mathematically separable as follows:

$$\varphi = \left(\begin{array}{l}\text{initial concentration}\\\text{reduced by dilution}\end{array}\right) \text{ x } \left(\begin{array}{l}\text{reduction by}\\\text{decay}\end{array}\right)$$

The decay factor equals the ratio of the decay rate of the i^{th} radionuclide divided by the initial decay rate of the first radionuclide assuming no dilution and is expressed as follows:

$$\text{decay factor} = \frac{\lambda_i \; N_i}{\lambda_i \, N_{1_o}}$$

where:

λ_i = decay constant of the i^{th} radionuclide
N_i = atom density of i^{th} radionuclide is sea water
N_{1_o} = initial atom density of first radionuclide (at time = 0)

The initial atom density N_{1_o} corresponds with the zero decay curve.

FIRST RADIONUCLIDE

For a single radionuclide or the first in a chain, the concentration can be expressed as follows:

$$\varphi(x,y) = \varphi_{1_o}(x,y) \cdot \frac{\lambda_1 N_1}{\lambda_1 N_{1_o}}$$

where $\varphi_{1_o}(x,y)$ = radionuclide concentration for no decay.

The decay formula for a single radionuclide is:

$$N_1 = N_{1_o} \; e^{-\lambda_1 t}$$

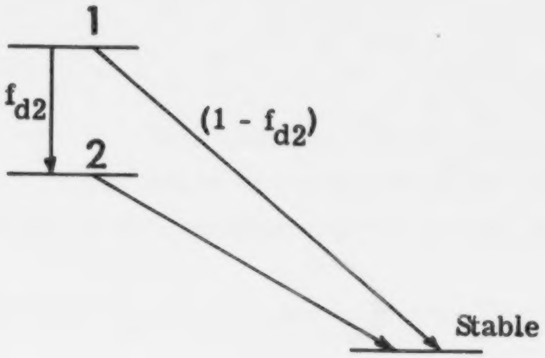
where t = time after release = $\frac{x}{U_o}$

Substituting:

$$\phi_1(x,y) = \frac{e^{-\frac{y^2}{2c^2x^2}}}{\sqrt{2\pi}\, D\, U_o\, cx} \cdot Q_1 \; e^{-\frac{1^x}{U_o}}$$

SECOND RADIONUCLIDE

The decay scheme of a two-radionuclide chain is shown schematically below:



A fraction, f_{d2}, of the first radionuclide decays to the second radionuclide and the remainder, $(1-f_{d2})$, decays directly to the stable nuclide. Considering both decay from the first radionuclide and direct release of the second radionuclide, the concentration of the second radionuclide is as follows:

$$\phi_2(x,y) = \text{decay from first radionuclide} + \text{direct release of second radionuclide}$$

$$\phi_2(x,y) = \phi_{1_o} \, f_{d2} \frac{\lambda_2 N_2}{\lambda_1 N_{1_o}} + \phi_{2_o} \frac{\lambda_2 N_2}{\lambda_2 N_{2_o}}$$

The value of N_2/N_{1_o} is the solution of the often-solved double decay chain problem, beginning with the differential equation:

$$\frac{dN_2}{dt} = \lambda_1 N_1 f_{d2} - \lambda_2 N_2$$

using $N_1 = N_{1_o} e^{-\lambda_1 t}$ and the boundary condition of $N_2 = 0$ when $t = 0$.

The solution is:

$$\frac{N_2}{N_{1_o}} = \frac{\lambda_1}{\lambda_2 - \lambda_1} \left(e^{-\lambda_1 t} - e^{-\lambda_2 t}\right)$$

By substituting for the variables, the concentration formula becomes:

$$\phi_2(x,y) = \frac{e^{-\frac{y^2}{2c^2x^2}}}{\sqrt{2\pi}\, D\, U_o\, cx} \quad f_2(x)$$

$$\text{where } f_2(x) = \frac{Q_1\, \lambda_2\, f_{d2}}{\lambda_2 - \lambda_1} \left(e^{-\frac{\lambda_1 x}{U_o}} - e^{-\frac{\lambda_1 x}{U_o}} \right) + Q_2\, e^{-\frac{\lambda_2 x}{U_o}}$$

THIRD RADIONUCLIDE

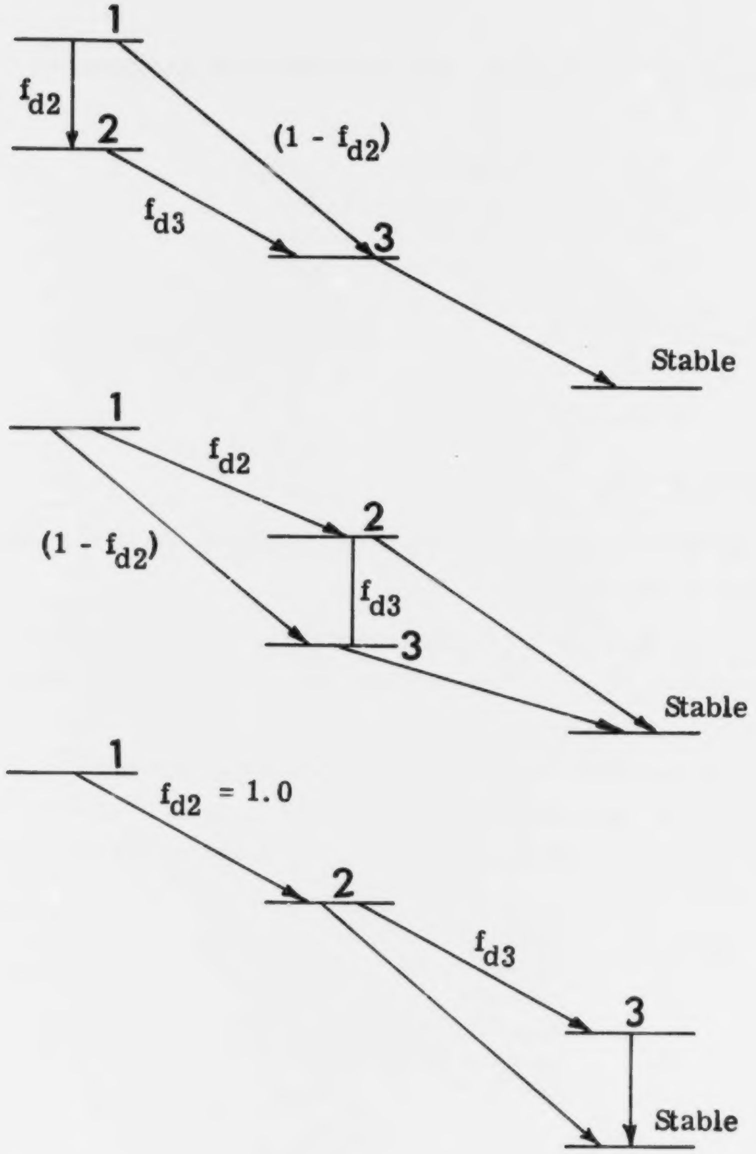
The decay scheme of a three-radionuclide chain can be any of those shown by the illustration on the next page.

A fraction, f_{d2}, of the first radionuclide decays to the second radionuclide, while the remainder, $(1-f_{d2})$, decays directly to the third radionuclide. Likewise a fraction, f_{d3}, of the second radionuclide decays to the third radionuclide, and the remainder $(1-f_{d3})$ decays to the stable nuclide. Considering decay from the first and second radionuclides and direct release of all three radionuclides, the concentration of the third radionuclide is as follows:

$$\phi_3(x,y) = \text{first radionuclide release decaying to second decaying to third} + \text{first radionuclide release decaying directly to third}$$

$$+ \text{second radionuclide rerelease decaying to third} + \text{direct release of third radionuclide}$$

$$\phi_3(x,y) = \phi_{1_o}\, f_{d2}\, f_{d3} \left[\frac{\lambda_3 N_3}{\lambda_1 N_{1_o}}\right]_{1,2,3} + \phi_{1_o}\, (1-f_{d2}) \left[\frac{\lambda_3 N_3}{\lambda_1 N_{1_o}}\right]_{1,3}$$


1
f_{d2}
2
$(1 - f_{d2})$
f_{d3}
3
Stable
1
f_{d2}
2
$(1 - f_{d2})$
f_{d3}
3
Stable
1
$f_{d2} = 1.0$
2
f_{d3}
3
Stable

$$+ \phi_{2_o} f_{d3} \left[\frac{\lambda_3 N_3}{\lambda_2 N_{2_o}}\right]_{2,3} + \phi_{3_o} \left[\frac{\lambda_3 N_3}{\lambda_3 N_{3_o}}\right]$$

The values of $\left[N_3/N_{2_o}\right]_{2,3}$ and $\left[N_3/N_{1_o}\right]_{1,3}$ are derived for the two-nuclide chain. The value of $\left[N_3/N_{1_o}\right]_{1,2,3}$ is the solution for the often-solved triple decay chain problem, beginning with the following differential equation:

$$\frac{dN_3}{dt} = \lambda_2 N_2 f_{d3} - \lambda_3 N_3$$

using $N_2 = \frac{\lambda_1 N_{1_0}}{\lambda_2 - \lambda_1} \left(e^{-\lambda_1 t} - e^{-\lambda_2 t}\right)$

and the boundary condition of $N_3 = 0$ when $t = 0$.

The solution is:

$$\frac{N_3}{N_{1_o}} = \frac{\lambda_1 \lambda_2}{(\lambda_3 - \lambda_2)(\lambda_2 - \lambda_1)} \left(e^{-\lambda_3 t} - e^{-\lambda_2 t}\right) - \frac{\lambda_1 \lambda_2}{(\lambda_3 - \lambda_1)(\lambda_2 - \lambda_1)} \left(e^{-\lambda_3 t} - e^{-\lambda_1 t}\right)$$

By substituting for the variables the concentration formula becomes:

$$\phi_3(x, y) = \frac{e^{-\frac{y^2}{2c^2x^2}}}{\sqrt{2\pi}\, DU_o cx} \cdot f_3(x)$$

where $$f_3(x) = \frac{\lambda_3 \lambda_2 Q_1 f_{d2} f_{d3}}{(\lambda_3 - \lambda_2)(\lambda_2 - \lambda_1)} \left(e^{-\frac{\lambda_3 x}{U_o}} - e^{-\frac{\lambda_2 x}{U_o}}\right)$$

$$- \frac{\lambda_3 \lambda_2 Q_1 f_{d2} f_{d3}}{(\lambda_3 - \lambda_1)(\lambda_2 - \lambda_1)} \left(e^{-\frac{\lambda_3 x}{U_o}} - e^{-\frac{\lambda_1 x}{U_o}}\right)$$

$$+ \frac{\lambda_3 Q_1 (1-f_{d2})}{\lambda_3 - \lambda_1} \left(e^{-\frac{\lambda_1 x}{U_o}} - e^{-\frac{\lambda_3 x}{U_o}} \right)$$

$$+ \frac{\lambda_3 Q_2 f_{d3}}{\lambda_3 - \lambda_2} \left(e^{-\frac{\lambda_2 x}{U_o}} - e^{-\frac{\lambda_3 x}{U_o}} \right)$$

$$+ Q_3 \; e^{-\frac{\lambda_3 x}{U_o}}$$

BATCH RELEASE

For batch release of radionuclides the concentration formula is:

$$\phi_i(x, r) = \frac{e^{-\frac{r^2}{2c^2x^2}}}{2\pi \, Dc^2x^2} \cdot f_i(x)$$

Appendix D
DISTRIBUTION OF RADIONUCLIDES IN THE SEA

This appendix is a computer printout tabulation that gives the down-current distribution of specific radionuclides at three current velocities (0.5, 4, and 24 nm/day) and distances to 40 nm from the site. The methods used in obtaining these results are explained in the body of the report. The radionuclides are presented in the order of increasing mass number in three sections:

	Pages
Normal operation, continuous release	248 through 265
Loss-of-coolant accident, batch release	266 through 285
Breach-of-containment accident, batch release	286 through 325

Computer limitations prevent the use of some conventional notation; thus, microcuries (μCi) is represented by UCI in the printout, and numbers following a plus or minus signify the power of 10 (e.g., .185 + 14 means $.185 \times 10^{14}$).

Down-current Distribution for NORMAL OPERATION, Continuous Release

```
 CURRENT   PLUME    HALF     VOLUME  CONCENTRATION    AVE. SPEC.
VELOCITY  LENGTH   WIDTH   IN PLUME       ISO-    AVE.   ACTIVITY
  NM/DAY      NM      NM         CC     UCI/CC  UCI/CC     UCI/GM

HALF LIFE   .447+04 DAYS              H 3
RELEASE RATE   .385+03 CURIES PER YEAR
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .108+00 GRAMS PER CC
MAXIMUM PERMISSIBLE                          .470-01      .140-02

     .50    1.00     .06    .185+14    .402-07 .804-07    .744-06
     .50    2.00     .12    .740+14    .201-07 .427-07    .395-06
     .50    4.00     .24    .296+15    .100-07 .220-07    .203-06
     .50   10.00     .61    .185+16    .401-08 .941-08    .871-07
     .50   20.00    1.22    .742+16    .200-08 .460-08    .426-07
     .50   40.00    2.44    .297+17    .992-09 .227-08    .210-07
    4.00    1.00     .06    .185+14    .502-08 .100-07    .930-07
    4.00    2.00     .12    .740+14    .251-08 .534-08    .494-07
    4.00    4.00     .24    .296+15    .126-08 .275-08    .254-07
    4.00   10.00     .61    .185+16    .502-09 .118-08    .109-07
    4.00   20.00    1.21    .740+16    .251-09 .577-09    .534-08
    4.00   40.00    2.43    .296+17    .125-09 .285-09    .264-08
   24.00    1.00     .06    .185+14    .837-09 .167-08    .155-07
   24.00    2.00     .12    .740+14    .419-09 .890-09    .824-08
   24.00    4.00     .24    .296+15    .209-09 .458-09    .424-08
   24.00   10.00     .61    .185+16    .837-10 .196-09    .182-08
   24.00   20.00    1.21    .740+16    .419-10 .962-10    .891-09
   24.00   40.00    2.43    .296+17    .209-10 .476-10    .441-09

HALF LIFE   .278+02 DAYS              CR 51
RELEASE RATE   .585-02 CURIES PER YEAR
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .500-10 GRAMS PER CC
MAXIMUM PERMISSIBLE                          .500-06      .310+06

     .50    1.00     .06    .189+14    .581-12 .119-11    .238-01
     .50    2.00     .13    .768+14    .276-12 .616-12    .123-01
     .50    4.00     .26    .318+15    .125-12 .301-12    .602-02
     .50   10.00     .72    .218+16    .371-13 .113-12    .226-02
     .50   20.00    1.62    .989+16    .113-13 .438-13    .877-03
     .50   40.00    3.89    .474+17    .208-14 .144-13    .288-03
    4.00    1.00     .06    .185+14    .759-13 .152-12    .304-02
    4.00    2.00     .12    .749+14    .377-13 .806-13    .161-02
    4.00    4.00     .24    .299+15    .186-13 .412-13    .824-03
    4.00   10.00     .62    .189+16    .717-14 .174-13    .347-03
    4.00   20.00    1.27    .775+16    .337-14 .823-14    .165-03
    4.00   40.00    2.65    .324+17    .149-14 .382-14    .763-04
   24.00    1.00     .06    .185+14    .127-13 .254-13    .509-03
   24.00    2.00     .12    .741+14    .635-14 .135-13    .270-03
   24.00    4.00     .24    .296+15    .317-14 .694-14    .139-03
   24.00   10.00     .61    .186+16    .126-14 .297-14    .594-04
   24.00   20.00    1.22    .746+16    .623-15 .145-14    .289-04
   24.00   40.00    2.47    .301+17    .305-15 .708-15    .142-04
```

```
 CURRENT   PLUME    HALF     VOLUME  CONCENTRATION    AVE. SPEC.
VELOCITY  LENGTH   WIDTH   IN PLUME       ISO-    AVE.   ACTIVITY
  NM/DAY      NM      NM         CC     UCI/CC  UCI/CC     UCI/GM

HALF LIFE   .303+03 DAYS              MN 54
RELEASE RATE   .419-04 CURIES PER YEAR
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .200-08 GRAMS PER CC
MAXIMUM PERMISSIBLE                          .380-08      .580+03

     .50    1.00     .06    .185+14    .435-14 .873-14    .436-05
     .60    2.00     .12    .743+14    .217-14 .463-14    .231-05
     .50    4.00     .24    .298+15    .107-14 .237-14    .118-05
     .50   10.00     .62    .188+16    .418-15 .100-14    .501-06
     .50   20.00    1.26    .766+16    .200-15 .479-15    .240-06
     .50   40.00    2.59    .317+17    .911-16 .226-15    .113-06
    4.00    1.00     .06    .185+14    .546-15 .109-14    .547-06
    4.00    2.00     .12    .740+14    .273-15 .581-15    .290-06
    4.00    4.00     .24    .296+15    .136-15 .299-15    .149-06
    4.00   10.00     .61    .185+16    .544-16 .128-15    .639-07
    4.00   20.00    1.22    .743+16    .270-16 .624-16    .312-07
    4.00   40.00    2.45    .299+17    .134-16 .307-16    .154-07
   24.00    1.00     .06    .185+14    .911-16 .182-15    .911-07
   24.00    2.00     .12    .740+14    .456-16 .968-16    .484-07
   24.00    4.00     .24    .296+15    .228-16 .498-16    .249-07
   24.00   10.00     .61    .185+16    .910-17 .214-16    .107-07
   24.00   20.00    1.21    .741+16    .455-17 .105-16    .523-08
   24.00   40.00    2.43    .296+17    .227-17 .517-17    .258-08

HALF LIFE   .949+03 DAYS              FE 55
RELEASE RATE   .230-03 CURIES PER YEAR
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .100-07 GRAMS PER CC
MAXIMUM PERMISSIBLE                          .250-07      .390+01

     .50    1.00     .06    .185+14    .240-13 .480-13    .480-05
     .50    2.00     .12    .741+14    .120-13 .255-13    .255-05
     .50    4.00     .24    .297+15    .597-14 .131-13    .131-05
     .50   10.00     .61    .186+16    .237-14 .559-14    .559-06
     .50   20.00    1.23    .748+16    .117-14 .272-14    .272-06
     .50   40.00    2.48    .303+17    .566-15 .132-14    .132-06
    4.00    1.00     .06    .185+14    .300-14 .600-14    .600-06
    4.00    2.00     .12    .740+14    .150-14 .319-14    .319-06
    4.00    4.00     .24    .296+15    .750-15 .164-14    .164-06
    4.00   10.00     .61    .185+16    .300-15 .703-15    .703-07
    4.00   20.00    1.21    .741+16    .150-15 .344-15    .344-07
    4.00   40.00    2.43    .297+17    .745-16 .170-15    .170-07
   24.00    1.00     .06    .185+14    .500-15 .100-14    .100-06
   24.00    2.00     .12    .740+14    .250-15 .531-15    .531-07
   24.00    4.00     .24    .296+15    .125-15 .274-15    .274-07
   24.00   10.00     .61    .185+16    .500-16 .117-15    .117-07
   24.00   20.00    1.21    .740+16    .250-16 .574-16    .574-08
   24.00   40.00    2.43    .296+17    .125-16 .284-16    .284-08
```

Down-current Distribution for NORMAL OPERATION, Continuous Release

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 CURRENT   PLUME     HALF      VOLUME      CONCENTRATION  AVE. SPEC.
VELOCITY  LENGTH    WIDTH    IN PLUME        ISO-    AVE.   ACTIVITY
  NM/DAY      NM       NM       CC        UCI/CC  UCI/CC     UCI/GM

HALF LIFE   .713+02 DAYS              CO 58
RELEASE RATE   .720-02 CURIES PER YEAR
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .500-09 GRAMS PER CC
MAXIMUM PERMISSIBLE                               .230-07      .890+02

     .50    1.00      .06     .186+14     .737-12 .149-11     .298-02
     .50    2.00      .12     .751+14     .362-12 .782-12     .156-02
     .50    4.00      .25     .305+15     .174-12 .395-12     .789-03
     .50   10.00      .65     .199+16     .619-13 .160-12     .321-03
     .50   20.00     1.39     .846+16     .255-13 .711-13     .142-03
     .50   40.00     3.08     .376+17     .864-14 .292-13     .584-04
    4.00    1.00      .06     .185+14     .937-13 .188-12     .375-03
    4.00    2.00      .12     .741+14     .468-13 .996-13     .199-03
    4.00    4.00      .24     .297+15     .233-13 .511-13     .102-03
    4.00   10.00      .61     .187+16     .917-14 .218-13     .435-04
    4.00   20.00     1.24     .754+16     .448-14 .105-13     .210-04
    4.00   40.00     2.52     .307+17     .213-14 .508-14     .102-04
   24.00    1.00      .06     .185+14     .157-13 .313-13     .626-04
   24.00    2.00      .12     .740+14     .782-14 .166-13     .333-04
   24.00    4.00      .24     .296+15     .391-14 .856-14     .171-04
   24.00   10.00      .61     .185+16     .156-14 .366-14     .733-05
   24.00   20.00     1.22     .742+16     .777-15 .179-14     .358-05
   24.00   40.00     2.44     .298+17     .385-15 .883-15     .177-05

HALF LIFE   .456+02 DAYS              FE 59
RELEASE RATE   .324-04 CURIES PER YEAR
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .100-07 GRAMS PER CC
MAXIMUM PERMISSIBLE                               .470-08      .890+00

     .50    1.00      .06     .187+14     .328-14 .666-14     .666-06
     .50    2.00      .12     .757+14     .159-14 .348-14     .348-06
     .50    4.00      .25     .310+15     .749-15 .174-14     .174-06
     .50   10.00      .68     .206+16     .250-15 .685-15     .685-07
     .50   20.00     1.48     .900+16     .921-16 .289-15     .289-07
     .50   40.00     3.39     .414+17     .251-16 .109-15     .109-07
    4.00    1.00      .06     .185+14     .421-15 .844-15     .844-07
    4.00    2.00      .12     .742+14     .210-15 .447-15     .447-07
    4.00    4.00      .24     .298+15     .104-15 .229-15     .229-07
    4.00   10.00      .62     .188+16     .407-16 .973-16     .973-08
    4.00   20.00     1.25     .762+16     .196-16 .467-16     .467-08
    4.00   40.00     2.57     .313+17     .908-17 .222-16     .222-08
   24.00    1.00      .06     .185+14     .704-16 .141-15     .141-07
   24.00    2.00      .12     .740+14     .352-16 .748-16     .748-08
   24.00    4.00      .24     .296+15     .176-16 .385-16     .385-08
   24.00   10.00      .61     .185+16     .700-17 .165-16     .165-08
   24.00   20.00     1.22     .744+16     .348-17 .804-17     .804-09
   24.00   40.00     2.45     .299+17     .172-17 .395-17     .395-09
```

```
 CURRENT   PLUME     HALF      VOLUME      CONCENTRATION  AVE. SPEC.
VELOCITY  LENGTH    WIDTH    IN PLUME        ISO-    AVE.   ACTIVITY
  NM/DAY      NM       NM       CC        UCI/CC  UCI/CC     UCI/GM

HALF LIFE   .192+04 DAYS              CO 60
RELEASE RATE   .900-03 CURIES PER YEAR
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .500-09 GRAMS PER CC
MAXIMUM PERMISSIBLE                               .150-07      .330+02

     .50    1.00      .06     .185+14     .939-13 .188-12     .376-03
     .50    2.00      .12     .740+14     .469-13 .998-13     .200-03
     .50    4.00      .24     .296+15     .234-13 .513-13     .103-03
     .50   10.00      .61     .186+16     .933-14 .220-13     .439-04
     .50   20.00     1.22     .744+16     .463-14 .107-13     .214-04
     .50   40.00     2.45     .299+17     .228-14 .526-14     .105-04
    4.00    1.00      .06     .185+14     .117-13 .235-13     .470-04
    4.00    2.00      .12     .740+14     .587-14 .125-13     .250-04
    4.00    4.00      .24     .296+15     .294-14 .642-14     .128-04
    4.00   10.00      .61     .185+16     .117-14 .275-14     .551-05
    4.00   20.00     1.21     .740+16     .586-15 .135-14     .270-05
    4.00   40.00     2.43     .296+17     .293-15 .666-15     .133-05
   24.00    1.00      .06     .185+14     .196-14 .391-14     .783-05
   24.00    2.00      .12     .740+14     .979-15 .208-14     .416-05
   24.00    4.00      .24     .296+15     .489-15 .107-14     .214-05
   24.00   10.00      .61     .185+16     .196-15 .459-15     .918-06
   24.00   20.00     1.21     .740+16     .978-16 .225-15     .450-06
   24.00   40.00     2.43     .296+17     .489-16 .111-15     .222-06

HALF LIFE   .613-01 DAYS              GE 78
RELEASE RATE   .331-07 CURIES PER. YEAR
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .700-10 GRAMS PER CC
MAXIMUM PERMISSIBLE                               .000         .000

     .50    1.00      .26     .802+14     .524-27 .851-22     .122-11
     .50    2.00      .73     .448+15     .397-37 .152-22     .218-12
     .50    4.00     2.06     .251+16     .000    .271-23     .388-13
     .50   10.00     8.11     .247+17     .000    .276-24     .394-14
     .50   20.00    22.92     .140+18     .000    .488-25     .697-15
     .50   40.00    64.78     .790+18     .000    .863-26     .123-15
    4.00    1.00      .11     .332+14     .256-19 .210-18     .300-08
    4.00    2.00      .28     .173+15     .758-21 .511-19     .730-09
    4.00    4.00      .76     .931+15     .133-23 .978-20     .140-09
    4.00   10.00     2.92     .892+16     .230-31 .102-20     .146-10
    4.00   20.00     8.18     .499+17     .000    .183-21     .261-11
    4.00   40.00    23.02     .281+18     .000    .325-22     .464-12
   24.00    1.00      .07     .217+14     .449-19 .114-18     .163-08
   24.00    2.00      .16     .977+14     .140-19 .482-19     .688-09
   24.00    4.00      .38     .466+15     .273-20 .167-19     .239-09
   24.00   10.00     1.32     .401+16     .648-22 .318-20     .454-10
   24.00   20.00     3.52     .215+17     .292-24 .621-21     .887-11
   24.00   40.00     9.65     .118+18     .118-28 .113-21     .162-11
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Down-current Distribution for NORMAL OPERATION, Continuous Release

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 CURRENT   PLUME    HALF     VOLUME      CONCENTRATION  AVE. SPEC.
VELOCITY  LENGTH   WIDTH   IN PLUME        150-    AVE.  ACTIVITY
  NM/DAY      NM      NM       CC        UCI/CC  UCI/CC     UCI/GM

HALF LIFE   .632-01 DAYS                 AS 78
RELEASE RATE    .650-07 CURIES PER YEAR
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .300-08 GRAMS PER CC
MAXIMUM PERMISSIBLE
                                                  .000         .000
DAUGHTER OF PREVIOUS RADIONUCLIDE, DECAY FRACTION =  1.0000

     .50     1.00     .25   .776+14   .185-25 .135-20    .449-12
     .50     2.00     .72   .438+15   .901-35 .239-31    .795-13
     .50     4.00     .00   .000      .000    .000       .000
     .50    10.00     .00   .000      .000    .000       .000
     .50    20.00     .00   .000      .000    .000       .000
     .50    40.00     .00   .000      .000    .000       .000
    4.00     1.00     .10   .302+14   .000    .000       .000
    4.00     2.00     .26   .160+15   .128-18 .725-18    .242-09
    4.00     4.00     .73   .885+15   .629-20 .191-18    .637-10
    4.00    10.00    2.84   .867+16   .210-22 .372-19    .124-10
    4.00    20.00    8.02   .989+17   .110-29 .381-20    .127-11
    4.00    40.00     .00   .000      .000    .674-21    .225-12
   24.00     1.00     .07   .203+14   .000    .000       .000
   24.00     2.00     .15   .893+14   .110-18 .251-18    .837-10
   24.00     4.00     .35   .422+15   .914-19 .116-18    .386-10
   24.00    10.00    1.21   .370+16   .108-19 .451-19    .150-10
   24.00    20.00    3.32   .203+17   .465-21 .101-19    .338-11
   24.00    40.00    9.30   .114+18   .384-23 .204-20    .680-12
                                      .331-27 .366-21    .122-12
HALF LIFE   .221-01 DAYS                 BR 84
RELEASE RATE    .100-02 CURIES PER YEAR
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .650-04 GRAMS PER CC
MAXIMUM PERMISSIBLE
                                                  .000         .000

     .50     1.00     .43   .131+15   .000    .503-26    .773-22
     .50     2.00    1.21   .739+15   .000    .893-27    .137-22
     .50     4.00    3.42   .417+16   .000    .158-27    .244-23
     .50    10.00   13.49   .911+17   .000    .160-28    .247-24
     .50    20.00   38.14   .233+18   .000    .284-29    .437-25
     .50    40.00  107.84   .132+19   .000    .502-30    .772-26
    4.00     1.00     .16   .495+14   .514-17 .518-15    .797-11
    4.00     2.00     .44   .270+15   .101-20 .970-16    .149-11
    4.00     4.00    1.23   .150+16   .786-28 .175-16    .269-12
    4.00    10.00    4.80   .146+17   .000    .179-17    .275-13
    4.00    20.00   13.53   .825+17   .000    .318-18    .489-14
    4.00    40.00   38.20   .466+18   .000    .563-19    .866-15
   24.00     1.00     .09   .263+14   .589-15 .226-14    .348-10
   24.00     2.00     .21   .129+15   .797-16 .727-15    .112-10
   24.00     4.00     .55   .669+15   .292-17 .174-15    .268-11
   24.00    10.00    2.04   .621+16   .460-21 .200-16    .308-12
   24.00    20.00    5.63   .344+17   .487-27 .362-17    .557-13
   24.00    40.00   15.75   .192+18   .000    .648-18    .997-14
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 CURRENT   PLUME    HALF     VOLUME      CONCENTRATION  AVE. SPEC.
VELOCITY  LENGTH   WIDTH   IN PLUME        150-    AVE.  ACTIVITY
  NM/DAY      NM      NM       CC        UCI/CC  UCI/CC     UCI/GM

HALF LIFE   .124-01 DAYS                 RB 88
RELEASE RATE    .550-01 CURIES PER YEAR
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .120-06 GRAMS PER CC
MAXIMUM PERMISSIBLE
                                                  .000         .000

     .50     1.00     .57   .175+15   .000    .615-35    .512-28
     .50     2.00    1.61   .984+15   .000    .109-35    .908-29
     .50     4.00    4.56   .556+16   .000    .193-36    .161-29
     .50    10.00   18.00   .549+17   .000    .195-37    .163-30
     .50    20.00   50.90   .311+18   .000    .345-38    .288-31
     .50    40.00  143.95   .176+19   .000    .000       .000
    4.00     1.00     .21   .641+14   .614-18 .133-14    .111-07
    4.00     2.00     .58   .355+15   .263-24 .240-15    .200-08
    4.00     4.00    1.63   .199+16   .960-37 .429-16    .357-09
    4.00    10.00    6.39   .195+17   .000    .437-17    .364-10
    4.00    20.00   18.03   .110+18   .000    .774-18    .645-11
    4.00    40.00   50.95   .622+18   .000    .137-18    .114-11
   24.00     1.00     .10   .311+14   .117-13 .747-13    .622-06
   24.00     2.00     .26   .160+15   .568-15 .195-13    .162-06
   24.00     4.00     .70   .854+15   .269-17 .387-14    .323-07
   24.00    10.00    2.67   .813+16   .922-24 .408-15    .340-08
   24.00    20.00    7.44   .454+17   .355-34 .731-16    .609-09
   24.00    40.00   20.92   .255+18   .000    .130-16    .108-09
HALF LIFE   .107-01 DAYS                 RB 89
RELEASE RATE    .136-02 CUNIES PER YEAR
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .120-06 GRAMS PER CC
MAXIMUM PERMISSIBLE
                                                  .000         .000

     .50     1.00     .62   .188+15   .000    .000       .000
     .50     2.00    1.74   .106+16   .000    .000       .000
     .50     4.00    4.91   .599+16   .000    .000       .000
     .50    10.00   19.38   .591+17   .000    .000       .000
     .50    20.00   54.80   .334+18   .000    .000       .000
     .50    40.00  154.96   .189+19   .000    .000       .000
    4.00     1.00     .22   .686+14   .165-20 .108-16    .902-10
    4.00     2.00     .62   .381+15   .766-28 .195-17    .162-10
    4.00     4.00    1.75   .213+16   .000    .348-18    .290-11
    4.00    10.00    6.87   .210+17   .000    .354-19    .295-12
    4.00    20.00   19.41   .118+18   .000    .627-20    .523-13
    4.00    40.00   54.84   .669+18   .000    .111-20    .925-14
   24.00     1.00     .11   .327+14   .199-15 .153-14    .128-07
   24.00     2.00     .28   .170+15   .670-17 .379-15    .316-08
   24.00     4.00     .75   .912+15   .152-19 .732-16    .610-09
   24.00    10.00    2.86   .872+16   .564-27 .766-17    .638-10
   24.00    20.00    8.00   .488+17   .000    .137-17    .114-10
   24.00    40.00   22.50   .274+18   .000    .243-18    .203-11
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Down-current Distribution for NORMAL OPERATION, Continuous Release

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 CURRENT   PLUME     HALF      VOLUME       CONCENTRATION  AVE. SPEC.
VELOCITY  LENGTH    WIDTH    IN PLUME        ISO-     AVE.   ACTIVITY
  NM/DAY      NM       NM       CC         UCI/CC  UCI/CC      UCI/GM

HALF LIFE   .527+02 DAYS               SR 89
RELEASE RATE   .143-03 CURIES PER YEAR
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .800-05 GRAMS PER CC
MAXIMUM PERMISSIBLE                                .790-05      .110+04
DAUGHTER OF PREVIOUS RADIONUCLIDE, DECAY FRACTION =  1.0000

     .50    1.00      .06     .187+14     .146-13 .295-13     .369-08
     .50    2.00      .12     .755+14     .710-14 .155-13     .193-08
     .50    4.00      .25     .308+15     .337-14 .774-14     .967-09
     .50   10.00      .67     .203+16     .115-14 .309-14     .386-09
     .50   20.00     1.44     .880+16     .442-15 .133-14     .166-09
     .50   40.00     3.28     .400+17     .131-15 .515-15     .643-10
    4.00    1.00      .06     .185+14     .186-14 .373-14     .467-09
    4.00    2.00      .12     .742+14     .929-15 .198-14     .247-09
    4.00    4.00      .24     .298+15     .461-15 .102-14     .127-09
    4.00   10.00      .61     .187+16     .181-15 .431-15     .539-10
    4.00   20.00     1.24     .759+16     .875-16 .208-15     .259-10
    4.00   40.00     2.55     .311+17     .410-16 .992-16     .124-10
   24.00    1.00      .06     .185+14     .311-15 .623-15     .778-10
   24.00    2.00      .12     .740+14     .156-15 .331-15     .413-10
   24.00    4.00      .24     .296+15     .777-16 .170-15     .213-10
   24.00   10.00      .61     .185+16     .310-16 .729-16     .911-11
   24.00   20.00     1.22     .743+16     .154-16 .356-16     .445-11
   24.00   40.00     2.45     .299+17     .762-17 .175-16     .219-11

HALF LIFE   .101+05 DAYS               SR 90
RELEASE RATE   .319-05 CURIES PER YEAR
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .800-05 GRAMS PER CC
MAXIMUM PERMISSIBLE                                .790-07      .420+01

     .50    1.00      .06     .185+14     .333-15 .666-15     .833-10
     .50    2.00      .12     .740+14     .166-15 .354-15     .442-10
     .50    4.00      .24     .296+15     .832-16 .182-15     .228-10
     .50   10.00      .61     .185+16     .333-16 .780-16     .976-11
     .50   20.00     1.21     .741+16     .166-16 .382-16     .478-11
     .50   40.00     2.43     .297+17     .828-17 .189-16     .236-11
    4.00    1.00      .06     .185+14     .416-16 .833-16     .104-10
    4.00    2.00      .12     .740+14     .208-16 .442-16     .553-11
    4.00    4.00      .24     .296+15     .104-16 .228-16     .285-11
    4.00   10.00      .61     .185+16     .416-17 .976-17     .122-11
    4.00   20.00     1.21     .740+16     .208-17 .478-17     .598-12
    4.00   40.00     2.43     .296+17     .104-17 .237-17     .296-12
   24.00    1.00      .06     .185+14     .694-17 .139-16     .173-11
   24.00    2.00      .12     .740+14     .347-17 .737-17     .921-12
   24.00    4.00      .24     .296+15     .173-17 .379-17     .474-12
   24.00   10.00      .61     .185+16     .694-18 .163-17     .203-12
   24.00   20.00     1.21     .740+16     .347-18 .797-18     .996-13
   24.00   40.00     2.43     .296+17     .173-18 .394-18     .493-13
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 CURRENT   PLUME     HALF      VOLUME       CONCENTRATION  AVE. SPEC.
VELOCITY  LENGTH    WIDTH    IN PLUME        ISO-     AVE.   ACTIVITY
  NM/DAY      NM       NM       CC         UCI/CC  UCI/CC      UCI/GM

HALF LIFE   .267+01 DAYS               Y  90
RELEASE RATE   .106-03 CURIES PER YEAR
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .300-09 GRAMS PER CC
MAXIMUM PERMISSIBLE                                .380-06      .300+05
DAUGHTER OF PREVIOUS RADIONUCLIDE, DECAY FRACTION =  1.0000

     .50    1.00      .07     .218+14     .672-14 .172-13     .574-04
     .50    2.00      .16     .982+14     .207-14 .724-14     .241-04
     .50    4.00      .38     .459+15     .420-15 .253-14     .843-05
     .50   10.00      .94     .287+16     .392-16 .597-15     .199-05
     .50   20.00     1.28     .781+16     .166-16 .237-15     .790-06
     .50   40.00     2.43     .297+17     .828-17 .716-16     .239-06
    4.00    1.00      .06     .190+14     .130-14 .268-14     .894-05
    4.00    2.00      .13     .776+14     .610-15 .138-14     .459-05
    4.00    4.00      .27     .324+15     .269-15 .664-15     .221-05
    4.00   10.00      .74     .225+16     .743-16 .242-15     .808-06
    4.00   20.00     1.69     .103+17     .204-16 .900-16     .300-06
    4.00   40.00     3.93     .480+17     .354-17 .287-16     .958-07
   24.00    1.00      .06     .186+14     .228-15 .459-15     .153-05
   24.00    2.00      .12     .746+14     .113-15 .242-15     .808-06
   24.00    4.00      .25     .301+15     .553-16 .123-15     .411-06
   24.00   10.00      .63     .192+16     .208-16 .513-16     .171-06
   24.00   20.00     1.31     .798+16     .935-17 .238-16     .794-07
   24.00   40.00     2.79     .341+17     .380-17 .106-16     .354-07

HALF LIFE   .403+00 DAYS               SR 91
RELEASE RATE   .836-04 CURIES PER YEAR
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .800-05 GRAMS PER CC
MAXIMUM PERMISSIBLE                                .400-04      .780+05

     .50    1.00      .12     .356+14     .280-15 .313-14     .391-09
     .50    2.00      .31     .187+15     .449-17 .710-15     .887-10
     .50    4.00      .83     .102+16     .231-20 .132-15     .166-10
     .50   10.00     3.21     .980+16     .101-29 .138-16     .172-11
     .50   20.00     9.01     .550+17     .000    .245-17     .307-12
     .50   40.00    25.36     .309+18     .000    .436-18     .545-13
    4.00    1.00      .07     .214+14     .710-15 .176-14     .220-09
    4.00    2.00      .16     .958+14     .231-15 .758-15     .948-10
    4.00    4.00      .37     .454+15     .489-16 .270-15     .338-10
    4.00   10.00     1.27     .387+16     .148-17 .539-16     .674-11
    4.00   20.00     3.38     .206+17     .101-19 .107-16     .134-11
    4.00   40.00     9.25     .113+18     .928-24 .197-17     .246-12
   24.00    1.00      .06     .190+14     .169-15 .351-15     .439-10
   24.00    2.00      .13     .781+14     .788-16 .179-15     .224-10
   24.00    4.00      .27     .328+15     .341-16 .857-16     .107-10
   24.00   10.00      .76     .231+16     .888-17 .306-16     .382-11
   24.00   20.00     1.77     .108+17     .217-17 .109-16     .136-11
   24.00   40.00     4.38     .534+17     .259-18 .317-17     .396-12
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Down-current Distribution for NORMAL OPERATION, Continuous Release

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 CURRENT   PLUME    HALF     VOLUME      CONCENTRATION  AVE. SPEC.
VELOCITY  LENGTH   WIDTH   IN PLUME        ISO-    AVE.   ACTIVITY
  NM/DAY      NM      NM       CC        UCI/CC  UCI/CC     UCI/GM

HALF LIFE   .588+02 DAYS              Y  91
RELEASE RATE   .759-01 CURIES PER YEAR
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .300-09 GRAMS PER CC
MAXIMUM PERMISSIBLE
                                               .570-06       .230+09
DAUGHTER OF PREVIOUS RADIONUCLIDE, DECAY FRACTION =  1.0000

     .50    1.00     .06    .187+14   .774-11 .157-10    .522-01
     .50    2.00     .12    .754+14   .378-11 .821-11    .274-01
     .50    4.00     .25    .307+15   .180-11 .412-11    .137-01
     .50   10.00     .66    .201+16   .626-12 .166-11    .552-02
     .50   20.00    1.42    .866+16   .247-12 .720-12    .240-02
     .50   40.00    3.20    .391+17   .772-13 .286-12    .953-03
    4.00    1.00     .06    .185+14   .988-12 .198-11    .659-02
    4.00    2.00     .12    .742+14   .492-12 .105-11    .350-02
    4.00    4.00     .24    .297+15   .245-12 .538-12    .179-02
    4.00   10.00     .61    .187+16   .962-13 .229-12    .763-03
    4.00   20.00    1.24    .757+16   .467-13 .110-12    .368-03
    4.00   40.00    2.54    .309+17   .220-13 .529-13    .176-03
   24.00    1.00     .06    .185+14   .165-12 .330-12    .110-02
   24.00    2.00     .12    .740+14   .825-13 .175-12    .584-03
   24.00    4.00     .24    .296+15   .412-13 .902-13    .301-03
   24.00   10.00     .61    .185+16   .164-13 .386-13    .129-03
   24.00   20.00    1.22    .743+16   .817-14 .189-13    .629-04
   24.00   40.00    2.44    .298+17   .405-14 .929-14    .310-04

HALF LIFE   .429+00 DAYS              Y  93
RELEASE RATE   .598-03 CURIES PER YEAR
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .300-09 GRAMS PER CC
MAXIMUM PERMISSIBLE
                                               .570-06       .130+06

     .50    1.00     .11    .348+14   .247-14 .248-13    .827-04
     .50    2.00     .30    .183+15   .488-16 .575-14    .192-04
     .50    4.00     .81    .989+15   .381-19 .108-14    .361-05
     .50   10.00    3.12    .951+16   .581-28 .113-15    .375-06
     .50   20.00    8.74    .533+17   .000    .201-16    .669-07
     .50   40.00   24.59    .300+18   .000    .357-17    .119-07
    4.00    1.00     .07    .212+14   .521-14 .128-13    .425-04
    4.00    2.00     .16    .946+14   .174-14 .556-14    .185-04
    4.00    4.00     .37    .446+15   .388-15 .202-14    .672-05
    4.00   10.00    1.24    .378+16   .138-16 .415-15    .138-05
    4.00   20.00    3.29    .201+17   .121-18 .838-16    .279-06
    4.00   40.00    8.99    .110+18   .188-22 .154-16    .513-07
   24.00    1.00     .06    .190+14   .122-14 .252-14    .838-05
   24.00    2.00     .13    .778+14   .568-15 .129-14    .429-05
   24.00    4.00     .27    .326+15   .248-15 .619-15    .206-05
   24.00   10.00     .75    .229+16   .664-16 .223-15    .744-06
   24.00   20.00    1.74    .106+17   .169-16 .807-16    .269-06
   24.00   40.00    4.28    .523+17   .220-17 .240-16    .801-07
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 CURRENT   PLUME    HALF     VOLUME      CONCENTRATION  AVE. SPEC.
VELOCITY  LENGTH   WIDTH   IN PLUME        ISO-    AVE.   ACTIVITY
  NM/DAY      NM      NM       CC        UCI/CC  UCI/CC     UCI/GM

HALF LIFE   .655+02 DAYS              ZR 95
RELEASE RATE   .144-05 CURIES PER YEAR
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .220-10 GRAMS PER CC
MAXIMUM PERMISSIBLE
                                               .950-06       .100+09

     .50    1.00     .06    .187+14   .147-15 .298-15    .136-04
     .50    2.00     .12    .752+14   .721-16 .156-15    .710-05
     .50    4.00     .25    .306+15   .345-16 .786-16    .357-05
     .50   10.00     .66    .200+16   .122-16 .318-16    .145-05
     .50   20.00    1.40    .854+16   .492-17 .140-16    .636-06
     .50   40.00    3.13    .382+17   .161-17 .566-17    .257-06
    4.00    1.00     .06    .185+14   .187-16 .375-16    .171-05
    4.00    2.00     .12    .742+14   .935-17 .199-16    .905-06
    4.00    4.00     .24    .297+15   .465-17 .102-16    .465-06
    4.00   10.00     .61    .187+16   .183-17 .435-17    .198-06
    4.00   20.00    1.24    .755+16   .891-18 .210-17    .956-07
    4.00   40.00    2.53    .308+17   .423-18 .101-17    .459-07
   24.00    1.00     .06    .185+14   .313-17 .626-17    .285-06
   24.00    2.00     .12    .740+14   .156-17 .333-17    .151-06
   24.00    4.00     .24    .296+15   .782-18 .171-17    .778-07
   24.00   10.00     .61    .185+16   .312-18 .733-18    .333-07
   24.00   20.00    1.22    .743+16   .155-18 .358-18    .163-07
   24.00   40.00    2.44    .298+17   .769-19 .176-18    .802-08

HALF LIFE   .350+02 DAYS              NB 95
RELEASE RATE   .148-03 CURIES PER YEAR
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .100-10 GRAMS PER CC
MAXIMUM PERMISSIBLE
                                               .950-06       .180+09
DAUGHTER OF PREVIOUS RADIONUCLIDE, DECAY FRACTION =  1.0000

     .50    1.00     .06    .188+14   .149-13 .303-13    .303-02
     .50    2.00     .12    .762+14   .714-14 .158-13    .158-02
     .50    4.00     .26    .314+15   .330-14 .778-14    .778-03
     .50   10.00     .69    .212+16   .104-14 .300-14    .300-03
     .50   20.00    1.54    .940+16   .353-15 .122-14    .122-03
     .50   40.00    3.62    .442+17   .811-16 .430-15    .430-04
    4.00    1.00     .06    .185+14   .192-14 .385-14    .385-03
    4.00    2.00     .12    .743+14   .956-15 .204-14    .204-03
    4.00    4.00     .24    .298+15   .473-15 .105-14    .105-03
    4.00   10.00     .62    .189+16   .184-15 .442-15    .442-04
    4.00   20.00    1.26    .768+16   .876-16 .211-15    .211-04
    4.00   40.00    2.61    .318+17   .397-16 .992-16    .992-05
   24.00    1.00     .06    .185+14   .322-15 .644-15    .644-04
   24.00    2.00     .12    .740+14   .161-15 .342-15    .342-04
   24.00    4.00     .24    .296+15   .802-16 .176-15    .176-04
   24.00   10.00     .61    .186+16   .319-16 .752-16    .752-05
   24.00   20.00    1.22    .745+16   .158-16 .367-16    .367-05
   24.00   40.00    2.46    .300+17   .779-17 .180-16    .180-05
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Down-current Distribution for NORMAL OPERATION, Continuous Release

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 CURRENT   PLUME    HALF     VOLUME      CONCENTRATION  AVE. SPEC.
VELOCITY  LENGTH   WIDTH   IN PLUME        ISO-    AVE.  ACTIVITY
  NM/DAY      NM      NM       CC        UCI/CC  UCI/CC    UCI/GM

HALF LIFE   .708+00 DAYS            ZR 97
RELEASE RATE   .660-04 CURIES PER YEAR
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .220-10 GRAMS PER CC
MAXIMUM PERMISSIBLE                                .320-06    .180+05

     .50    1.00     .10   .295+14   .973-15 .518-14   .235-03
     .50    2.00     .25   .150+15   .687-16 .144-14   .654-04
     .50    4.00     .65   .792+15   .685-18 .300-15   .136-04
     .50   10.00    2.46   .749+16   .217-23 .320-16   .145-05
     .50   20.00    6.84   .417+17   .342-32 .574-17   .261-06
     .50   40.00   19.20   .234+18   .000    .102-17   .465-07
    4.00    1.00     .07   .202+14   .674-15 .152-14   .693-04
    4.00    2.00     .14   .871+14   .264-15 .714-15   .325-04
    4.00    4.00     .32   .394+15   .809-16 .292-15   .133-04
    4.00   10.00    1.04   .316+16   .745-17 .750-16   .341-05
    4.00   20.00    2.67   .163+17   .323-18 .177-16   .805-06
    4.00   40.00    7.16   .873+17   .121-20 .344-17   .156-06
   24.00    1.00     .06   .188+14   .138-15 .281-15   .128-04
   24.00    2.00     .13   .763+14   .662-16 .146-15   .664-05
   24.00    4.00     .26   .314+15   .305-16 .721-16   .328-05
   24.00   10.00     .70   .213+16   .955-17 .277-16   .126-05
   24.00   20.00    1.55   .948+16   .317-17 .111-16   .507-06
   24.00   40.00    3.67   .447+17   .702-18 .389-17   .177-06

HALF LIFE   .278+01 DAYS            MO 99
RELEASE RATE   .410+00 CURIES PER YEAR
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .100-07 GRAMS PER CC
MAXIMUM PERMISSIBLE                                .750-06    .270+09

     .50    1.00     .07   .218+14   .260-10 .667-10   .667-02
     .50    2.00     .16   .989+14   .790-11 .279-10   .279-02
     .50    4.00     .39   .474+15   .146-11 .952-11   .952-03
     .50   10.00    1.35   .411+16   .293-13 .176-11   .176-03
     .50   20.00    3.61   .220+17   .100-15 .340-12   .340-04
     .50   40.00    9.91   .121+18   .234-20 .619-13   .619-05
    4.00    1.00     .06   .189+14   .503-11 .104-10   .104-02
    4.00    2.00     .13   .775+14   .236-11 .533-11   .533-03
    4.00    4.00     .27   .324+15   .104-11 .257-11   .257-03
    4.00   10.00     .74   .226+16   .287-12 .938-12   .938-04
    4.00   20.00    1.71   .104+17   .769-13 .346-12   .346-04
    4.00   40.00    4.18   .509+17   .111-13 .106-12   .106-04
   24.00    1.00     .06   .186+14   .883-12 .177-11   .177-03
   24.00    2.00     .12   .746+14   .437-12 .937-12   .937-04
   24.00    4.00     .25   .301+15   .214-12 .477-12   .477-04
   24.00   10.00     .63   .192+16   .804-13 .199-12   .199-04
   24.00   20.00    1.31   .798+16   .362-13 .921-13   .921-05
   24.00   40.00    2.79   .341+17   .147-13 .411-13   .411-05
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 CURRENT   PLUME    HALF     VOLUME      CONCENTRATION  AVE. SPEC.
VELOCITY  LENGTH   WIDTH   IN PLUME        ISO-    AVE.  ACTIVITY
  NM/DAY      NM      NM       CC        UCI/CC  UCI/CC    UCI/GM

HALF LIFE   .395+02 DAYS            RU 103
RELEASE RATE   .116-03 CURIES PER YEAR
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .000    GRAMS PER CC
MAXIMUM PERMISSIBLE                                .130-05    .000

     .50    1.00     .06   .188+14   .117-13 .238-13   .000
     .50    2.00     .12   .760+14   .564-14 .124-13   .000
     .50    4.00     .26   .312+15   .263-14 .615-14   .000
     .50   10.00     .69   .209+16   .853-15 .240-14   .000
     .50   20.00    1.51   .922+16   .300-15 .990-15   .000
     .50   40.00    3.52   .429+17   .744-16 .360-15   .000
    4.00    1.00     .06   .185+14   .151-14 .302-14   .000
    4.00    2.00     .12   .743+14   .750-15 .160-14   .000
    4.00    4.00     .24   .298+15   .372-15 .820-15   .000
    4.00   10.00     .62   .188+16   .145-15 .347-15   .000
    4.00   20.00    1.25   .765+16   .693-16 .166-15   .000
    4.00   40.00    2.59   .316+17   .318-16 .786-16   .000
   24.00    1.00     .06   .185+14   .252-15 .504-15   .000
   24.00    2.00     .12   .740+14   .126-15 .268-15   .000
   24.00    4.00     .24   .296+15   .629-16 .138-15   .000
   24.00   10.00     .61   .186+16   .250-16 .589-16   .000
   24.00   20.00    1.22   .744+16   .124-16 .288-16   .000
   24.00   40.00    2.45   .299+17   .613-17 .141-16   .000

HALF LIFE   .199+01 DAYS            RH 105
RELEASE RATE   .161-04 CURIES PER YEAR.
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .000    GRAMS PER CC
MAXIMUM PERMISSIBLE                                .190-05    .000

     .50    1.00     .08   .243+14   .665-15 .211-14   .000
     .50    2.00     .19   .116+15   .132-15 .758-15   .000
     .50    4.00     .48   .586+15   .103-16 .207-15   .000
     .50   10.00    1.75   .533+16   .158-19 .274-16   .000
     .50   20.00    4.79   .292+17   .745-24 .500-17   .000
     .50   40.00   13.33   .163+18   .330-32 .898-18   .000
    4.00    1.00     .06   .193+14   .187-15 .397-15   .000
    4.00    2.00     .13   .805+14   .833-16 .198-15   .000
    4.00    4.00     .28   .346+15   .330-16 .907-16   .000
    4.00   10.00     .84   .256+16   .659-17 .294-16   .000
    4.00   20.00    2.04   .124+17   .103-17 .908-17   .000
    4.00   40.00    5.23   .638+17   .510-19 .221-17   .000
   24.00    1.00     .06   .186+14   .343-16 .694-16   .000
   24.00    2.00     .12   .751+14   .168-16 .365-16   .000
   24.00    4.00     .25   .305+15   .810-17 .184-16   .000
   24.00   10.00     .65   .199+16   .289-17 .747-17   .000
   24.00   20.00    1.39   .845+16   .119-17 .332-17   .000
   24.00   40.00    3.08   .375+17   .404-18 .136-17   .000
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Down-current Distribution for NORMAL OPERATION, Continuous Release

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 CURRENT   PLUME     HALF      VOLUME       CONCENTRATION  AVE. SPEC.
VELOCITY  LENGTH    WIDTH    IN PLUME        150-    AVE.    ACTIVITY
  NM/DAY      NM       NM       CC          UCI/CC  UCI/CC     UCI/GM

HALF LIFE   .368+03 DAYS               RU 106
RELEASE RATE   .446-05 CURIES PER YEAR
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .000    GRAMS PER CC
MAXIMUM PERMISSIBLE                            .160-06       .000

     .50     1.00      .06     .185+14    .964-15 .929-15    .000
     .50     2.00      .12     .742+14    .231-15 .493-15    .000
     .50     4.00      .24     .298+15    .115-15 .253-75    .000
     .50    10.00      .62     .188+16    .448-16 .107-15    .000
     .50    20.00     1.25     .762+16    .216-16 .514-16    .000
     .50    40.00     2.57     .313+17    .100-16 .245-16    .000
    4.00     1.00      .06     .185+14    .582-16 .116-15    .000
    4.00     2.00      .12     .740+14    .291-16 .618-16    .000
    4.00     4.00      .24     .296+15    .145-16 .318-16    .000
    4.00    10.00      .61     .185+16    .579-17 .136-16    .000
    4.00    20.00     1.22     .743+16    .288-17 .665-17    .000
    4.00    40.00     2.44     .298+17    .143-17 .328-17    .000
   24.00     1.00      .06     .185+14    .970-17 .194-16    .000
   24.00     2.00      .12     .740+14    .485-17 .103-16    .000
   24.00     4.00      .24     .296+15    .242-17 .530-17    .000
   24.00    10.00      .61     .185+16    .969-18 .227-17    .000
   24.00    20.00     1.21     .740+16    .484-18 .111-17    .000
   24.00    40.00     2.43     .296+17    .242-18 .550-18    .000

HALF LIFE   .561+00 DAYS               PD 109
RELEASE RATE   .316-06 CURIES PER YEAR
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .000    GRAMS PER CC
MAXIMUM PERMISSIBLE                            .130-05       .000

     .50     1.00      .10     .317+14    .279-17 .192-16    .000
     .50     2.00      .27     .164+15    .118-18 .489-17    .000
     .50     4.00      .72     .877+15    .921-21 .961-18    .000
     .50    10.00     2.74     .837+16    .615-28 .101-18    .000
     .50    20.00     7.66     .467+17    .000    .181-19    .000
     .50    40.00    21.54     .263+18    .000    .321-20    .000
    4.00     1.00      .07     .206+14    .303-17 .707-17    .000
    4.00     2.00      .15     .902+14    .111-17 .321-17    .000
    4.00     4.00      .34     .416+15    .300-18 .125-17    .000
    4.00    10.00     1.12     .343+16    .188-19 .292-18    .000
    4.00    20.00     2.94     .179+17    .428-21 .635-19    .000
    4.00    40.00     7.95     .969+17    .445-24 .119-19    .000
   24.00     1.00      .06     .189+14    .653-18 .134-17    .000
   24.00     2.00      .13     .769+14    .310-18 .692-18    .000
   24.00     4.00      .26     .319+15    .190-18 .338-18    .000
   24.00    10.00      .72     .219+16    .411-19 .126-18    .000
   24.00    20.00     1.63     .996+16    .123-19 .486-19    .000
   24.00    40.00     3.93     .479+17    .219-20 .158-19    .000
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 CURRENT   PLUME     HALF      VOLUME       CONCENTRATION  AVE. SPEC.
VELOCITY  LENGTH    WIDTH    IN PLUME        150-    AVE.    ACTIVITY
  NM/DAY      NM       NM       CC          UCI/CC  UCI/CC     UCI/GM

HALF LIFE   .750+01 DAYS               AG 111
RELEASE RATE   .428-06 CURIES PER YEAR
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .300-09 GRAMS PER CC
MAXIMUM PERMISSIBLE                            .150-07       .130+01

     .50     1.00      .06     .198+14    .371-16 .815-16    .272-06
     .50     2.00      .14     .841+14    .154-16 .393-16    .131-06
     .50     4.00      .31     .372+15    .533-17 .169-16    .564-07
     .50    10.00      .95     .290+16    .704-18 .480-17    .160-07
     .50    20.00     2.40     .146+17    .555-19 .126-17    .419-08
     .50    40.00     6.34     .773+17    .688-21 .261-18    .868-09
    4.00     1.00      .06     .187+14    .546-17 .110-16    .368-07
    4.00     2.00      .12     .753+14    .267-17 .579-17    .193-07
    4.00     4.00      .25     .307+15    .127-17 .291-17    .970-08
    4.00    10.00      .66     .201+16    .443-18 .117-17    .390-08
    4.00    20.00     1.42     .864+16    .176-18 .510-18    .170-08
    4.00    40.00     3.19     .389+17    .554-19 .203-18    .678-09
   24.00     1.00      .06     .185+14    .927-18 .186-17    .619-08
   24.00     2.00      .12     .742+14    .462-18 .985-18    .328-08
   24.00     4.00      .24     .298+15    .229-18 .505-18    .168-08
   24.00    10.00      .62     .188+16    .896-19 .214-18    .714-09
   24.00    20.00     1.25     .762+16    .431-19 .103-18    .343-09
   24.00    40.00     2.57     .313+17    .200-19 .488-19    .163-09

HALF LIFE   .223+01 DAYS               CD 115
RELEASE RATE   .605-07 CURIES PER YEAR
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .110-09 GRAMS PER CC
MAXIMUM PERMISSIBLE                            .570-08       .710+03

     .50     1.00      .07     .226+14    .339-17 .926-17    .842-07
     .50     2.00      .17     .104+15    .911-18 .369-17    .336-07
     .50     4.00      .42     .509+15    .131-18 .117-17    .106-07
     .50    10.00     1.47     .449+16    .126-20 .191-18    .174-08
     .50    20.00     3.98     .243+17    .126-23 .359-19    .326-09
     .50    40.00    11.00     .134+18    .252-29 .650-20    .591-10
    4.00     1.00      .06     .191+14    .731-18 .152-17    .138-07
    4.00     2.00      .13     .784+14    .338-18 .774-18    .703-08
    4.00     4.00      .27     .330+15    .145-18 .368-18    .334-08
    4.00    10.00      .77     .235+16    .363-19 .129-18    .118-08
    4.00    20.00     1.81     .110+17    .835-20 .451-19    .410-09
    4.00    40.00     4.50     .549+17    .882-21 .127-19    .116-09
   24.00     1.00      .06     .186+14    .130-18 .261-18    .238-08
   24.00     2.00      .12     .747+14    .641-19 .138-18    .125-08
   24.00     4.00      .25     .302+15    .312-19 .700-19    .636-09
   24.00    10.00      .64     .194+16    .116-19 .290-19    .263-09
   24.00    20.00     1.33     .812+16    .508-20 .133-19    .121-09
   24.00    40.00     2.88     .351+17    .196-20 .577-20    .525-10
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Down-current Distribution for NORMAL OPERATION, Continuous Release

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 CURRENT   PLUME     HALF      VOLUME      CONCENTRATION  AVE. SPEC.
VELOCITY  LENGTH    WIDTH    IN PLUME        ISO-     AVE.   ACTIVITY
  NM/DAY      NM       NM        CC        UCI/CC   UCI/CC     UCI/GM

HALF LIFE   .250+03 DAYS                SN119M
RELEASE RATE   .204-06 CURIES PER YEAR
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .300-08 GRAMS PER CC
MAXIMUM PERMISSIBLE                              .000          .000

      .50     1.00      .06     .185+14    .212-16 .425-16    .192-07
      .50     2.00      .12     .743+14    .105-16 .225-16    .750-08
      .50     4.00      .24     .299+15    .521-17 .115-16    .384-08
      .50    10.00      .62     .189+16    .201-17 .486-17    .162-08
      .50    20.00     1.26     .772+16    .953-18 .231-17    .770-09
      .50    40.00     2.63     .321+17    .427-18 .108-17    .360-09
     4.00     1.00      .06     .185+14    .266-17 .532-17    .177-08
     4.00     2.00      .12     .740+14    .133-17 .283-17    .992-09
     4.00     4.00      .24     .296+15    .664-18 .145-17    .485-09
     4.00    10.00      .61     .185+16    .264-18 .622-18    .207-09
     4.00    20.00     1.22     .744+16    .131-18 .309-18    .101-09
     4.00    40.00     2.45     .299+17    .647-19 .149-18    .497-10
    24.00     1.00      .06     .185+14    .444-18 .887-18    .296-09
    24.00     2.00      .12     .740+14    .222-18 .471-18    .157-09
    24.00     4.00      .24     .296+15    .111-18 .243-18    .809-10
    24.00    10.00      .61     .185+16    .443-19 .109-18    .347-10
    24.00    20.00     1.21     .741+16    .221 19 .509-19    .170-10
    24.00    40.00     2.43     .297+17    .110-19 .252-19    .839-11

HALF LIFE   .115+01 DAYS                SN 121
RELEASE RATE   .138-06 CURIES PER YEAR
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .300-08 GRAMS PER CC
MAXIMUM PERMISSIBLE                              .000          .000

      .50     1.00      .08     .258+14    .432-17 .158-16    .526-08
      .50     2.00      .21     .126+15    .647-18 .521-17    .174-08
      .50     4.00      .53     .648+15    .290-19 .128-17    .428-09
      .50    10.00     1.96     .599+16    .840-23 .152-18    .506-10
      .50    20.00     5.42     .331+17    .245-28 .275-19    .917-11
      .50    40.00    15.14     .185+18    .000    .493-20    .164-11
     4.00     1.00      .06     .196+14    .155-17 .339-17    .111-08
     4.00     2.00      .13     .823+14    .666-18 .164-17    .596-09
     4.00     4.00      .29     .359+15    .246-18 .727-18    .242-09
     4.00    10.00      .90     .274+16    .399-19 .220-18    .733-10
     4.00    20.00     2.23     .136+17    .442-20 .620-19    .207-10
     4.00    40.00     5.81     .709+17    .109-21 .137-19    .457-11
    24.00     1.00      .06     .187+14    .293-18 .593-18    .198-09
    24.00     2.00      .12     .754+14    .143-18 .311-18    .104-09
    24.00     4.00      .25     .307+15    .679-19 .156-18    .519-10
    24.00    10.00      .66     .202+16    .234-19 .623-19    .208-10
    24.00    20.00     1.43     .874+16    .908-20 .269-19    .897-11
    24.00    40.00     3.25     .396+17    .275-20 .105-19    .352-11
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 CURRENT   PLUME     HALF      VOLUME      CONCENTRATION  AVE: SPEC.
VELOCITY  LENGTH    WIDTH    IN PLUME        ISO-     AVE.   ACTIVITY
  NM/DAY      NM       NM        CC        UCI/CC   UCI/CC     UCI/GM

HALF LIFE   .125+03 DAYS                SN 123
RELEASE RATE   .117-07 CURIES PER YEAR
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .300-08 GRAMS PER CC
MAXIMUM PERMISSIBLE                              .000          .000

      .50     1.00      .06     .186+14    .121-17 .243-17    .810-09
      .50     2.00      .12     .746+14    .597-18 .128-17    .428-09
      .50     4.00      .25     .301+15    .292-18 .652-18    .217-09
      .50    10.00      .63     .193+16    .109-18 .271-18    .904-10
      .50    20.00     1.31     .802+16    .489-19 .125-18    .418-10
      .50    40.00     2.82     .344+17    .196-19 .555-19    .185-10
     4.00     1.00      .06     .185+14    .152-18 .305-18    .102-09
     4.00     2.00      .12     .741+14    .761-19 .162-18    .540-10
     4.00     4.00      .24     .297+15    .380-19 .833-19    .278-10
     4.00    10.00      .61     .186+16    .151-19 .356-19    .119-10
     4.00    20.00     1.23     .748+16    .743-20 .173-19    .576-11
     4.00    40.00     2.48     .302+17    .361-20 .843-20    .281-11
    24.00     1.00      .06     .185+14    .254-19 .509-19    .170-10
    24.00     2.00      .12     .740+14    .127-19 .270-19    .901-11
    24.00     4.00      .24     .296+15    .636-20 .139-19    .464-11
    24.00    10.00      .61     .185+16    .254-20 .596-20    .199-11
    24.00    20.00     1.22     .741+16    .127-20 .292-20    .972-12
    24.00    40.00     2.43     .297+17    .630-21 .149-20    .480-12

HALF LIFE   .940+01 DAYS                SN 125
RELEASE RATE   .130-08 CURIES PER YEAR
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .300-08 GRAMS PER CC
MAXIMUM PERMISSIBLE                              .320-04       .310+03

      .50     1.00      .06     .195+14    .117-18 .252-18    .840-10
      .50     2.00      .13     .821+14    .505-19 .124-18    .413-10
      .50     4.00      .29     .358+15    .188-19 .551-19    .184-10
      .50    10.00      .89     .272+16    .311-20 .168-19    .559-11
      .50    20.00     2.21     .135+17    .356-21 .476-20    .159-11
      .50    40.00     5.76     .703+17    .931-23 .106-20    .354-12
     4.00     1.00      .06     .186+14    .167-19 .336-19    .112-10
     4.00     2.00      .12     .751+14    .818-20 .177-19    .589-11
     4.00     4.00      .25     .309+15    .394-20 .892-20    .297-11
     4.00    10.00      .65     .198+16    .141-20 .369-20    .121-11
     4.00    20.00     1.38     .841+16    .587-21 .162-20    .540-12
     4.00    40.00     3.05     .372+17    .203-21 .672-21    .224-12
    24.00     1.00      .06     .185+14    .282-20 .565-20    .188-11
    24.00     2.00      .12     .742+14    .141-20 .299-20    .998-12
    24.00     4.00      .24     .297+15    .698-21 .154-20    .512-12
    24.00    10.00      .61     .187+16    .274-21 .653-21    .218-12
    24.00    20.00     1.24     .758+16    .133-21 .315-21    .105-12
    24.00    40.00     2.54     .310+17    .625-22 .151-21    .502-13
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Down-current Distribution for NORMAL OPERATION, Continuous Release

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 CURRENT   PLUME     HALF      VOLUME       CONCENTRATION  AVE. SPEC.
VELOCITY  LENGTH    WIDTH    IN PLUME         ISO-     AVE.   ACTIVITY
  NM/DAY      NM       NM       CC          UCI/CC  UCI/CC      UCI/GM

HALF LIFE   .989+03 DAYS                 SB 125
RELEASE RATE   .103-06 CURIES PER YEAR
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .500-09 GRAMS PER CC
MAXIMUM PERMISSIBLE                               .160-06        .700+02
DAUGHTER OF PREVIOUS RADIONUCLIDE, DECAY FRACTION =  1.0000

     .50     1.00       .06     .185+14     .107-16 .215-16     .430-07
     .50     2.00       .12     .741+14     .536-17 .114-16     .228-07
     .50     4.00       .24     .297+15     .267-17 .586-17     .117-07
     .50    10.00       .61     .186+16     .106-17 .250-17     .501-08
     .50    20.00      1.23     .748+16     .523-18 .122-17     .243-08
     .50    40.00      2.48     .302+17     .254-18 .594-18     .119-08
    4.00     1.00       .06     .185+14     .134-17 .269-17     .538-08
    4.00     2.00       .12     .740+14     .672-18 .143-17     .286-08
    4.00     4.00       .24     .296+15     .336-18 .735-18     .147-08
    4.00    10.00       .61     .185+16     .134-18 .315-18     .630-09
    4.00    20.00      1.21     .741+16     .670-19 .154-18     .308-09
    4.00    40.00      2.43     .297+17     .334-19 .761-19     .152-09
   24.00     1.00       .06     .185+14     .224-18 .448-18     .896-09
   24.00     2.00       .12     .740+14     .112-18 .238-18     .476-09
   24.00     4.00       .24     .296+15     .560-19 .123-18     .245-09
   24.00    10.00       .61     .185+16     .224-19 .525-19     .105-09
   24.00    20.00      1.21     .740+16     .112-19 .257-19     .515-10
   24.00    40.00      2.43     .296+17     .559-20 .127-19     .255-10

HALF LIFE   .580+02 DAYS                 TE125M
RELEASE RATE   .106-04 CURIES PER YEAR
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .000    GRAMS PER CC
MAXIMUM PERMISSIBLE                               .160-05        .700+00
DAUGHTER OF PREVIOUS RADIONUCLIDE, DECAY FRACTION =   .2200

     .50     1.00       .06     .187+14     .108-14 .219-14     .000
     .50     2.00       .12     .754+14     .528-15 .115-14     .000
     .50     4.00       .25     .307+15     .251-15 .575-15     .000
     .50    10.00       .66     .202+16     .872-16 .231-15     .000
     .50    20.00      1.42     .868+16     .344-16 .100-15     .000
     .50    40.00      3.21     .391+17     .107-16 .398-16     .000
    4.00     1.00       .06     .185+14     .138-15 .276-15     .000
    4.00     2.00       .12     .742+14     .688-16 .147-15     .000
    4.00     4.00       .24     .297+15     .342-16 .752-16     .000
    4.00    10.00       .61     .187+16     .134-16 .320-16     .000
    4.00    20.00      1.24     .757+16     .652-17 .154-16     .000
    4.00    40.00      2.54     .310+17     .307-17 .739-17     .000
   24.00     1.00       .06     .185+14     .230-16 .461-16     .000
   24.00     2.00       .12     .740+14     .115-16 .245-16     .000
   24.00     4.00       .24     .296+15     .575-17 .126-16     .000
   24.00    10.00       .61     .185+16     .229-17 .539-17     .000
   24.00    20.00      1.22     .743+16     .114-17 .263-17     .000
   24.00    40.00      2.45     .298+17     .565-18 .130-17     .000
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 CURRENT   PLUME     HALF      VOLUME       CONCENTRATION  AVE. SPEC.
VELOCITY  LENGTH    WIDTH    IN PLUME         ISO-     AVE.   ACTIVITY
  NM/DAY      NM       NM       CC          UCI/CC  UCI/CC      UCI/GM

HALF LIFE   .375+00 DAYS                 SB 126
RELEASE RATE   .233-07 CURIES PER YEAR
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .500-09 GRAMS PER CC
MAXIMUM PERMISSIBLE                               .000           .000

     .50     1.00       .12     .366+14     .604-19 .766-18     .153-08
     .50     2.00       .32     .193+15     .749-21 .170-18     .340-09
     .50     4.00       .86     .105+16     .231-24 .315-19     .630-10
     .50    10.00      3.33     .101+17     .216-34 .327-20     .653-11
     .50    20.00      9.33     .569+17     .000    .582-21     .116-11
     .50    40.00     26.29     .321+18     .000    .103-21     .207-12
    4.00     1.00       .07     .216+14     .192-18 .483-18     .965-09
    4.00     2.00       .16     .973+14     .603-19 .205-18     .410-09
    4.00     4.00       .38     .464+15     .120-19 .716-19     .143-09
    4.00    10.00      1.31     .398+16     .300-21 .138-19     .275-10
    4.00    20.00      3.49     .213+17     .148-23 .270-20     .540-11
    4.00    40.00      9.57     .117+18     .716-28 .493-21     .985-12
   24.00     1.00       .06     .191+14     .969-19 .975-19     .195-09
   24.00     2.00       .13     .784+14     .217-19 .497-19     .994-10
   24.00     4.00       .27     .330+15     .931-20 .236-19     .473-10
   24.00    10.00       .77     .234+16     .235-20 .833-20     .167-10
   24.00    20.00      1.80     .110+17     .543-21 .291-20     .582-11
   24.00    40.00      4.49     .548+17     .582-22 .825-21     .165-11

HALF LIFE   .388+01 DAYS                 SB 127
RELEASE RATE   .284-05 CURIES PER YEAR
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .500-09 GRAMS PER CC
MAXIMUM PERMISSIBLE                               .000           .000

     .50     1.00       .07     .209+14     .207-15 .496-15     .992-06
     .50     2.00       .15     .925+14     .726-16 .221-15     .441-06
     .50     4.00       .35     .431+15     .178-16 .828-16     .166-06
     .50    10.00      1.18     .361+16     .833-18 .181-16     .361-07
     .50    20.00      3.12     .190+17     .117-19 .377-17     .754-08
     .50    40.00      8.49     .104+18     .962-23 .698-18     .140-08
    4.00     1.00       .06     .188+14     .354-16 .725-16     .145-06
    4.00     2.00       .13     .766+14     .169-16 .376-16     .752-07
    4.00     4.00       .26     .316+15     .775-17 .185-16     .369-07
    4.00    10.00       .71     .215+16     .237-17 .703-17     .141-07
    4.00    20.00      1.58     .966+16     .759-18 .278-17     .556-08
    4.00    40.00      3.76     .459+17     .155-18 .946-18     .189-08
   24.00     1.00       .06     .186+14     .613-17 .123-16     .246-07
   24.00     2.00       .12     .744+14     .304-17 .651-17     .130-07
   24.00     4.00       .25     .299+15     .150-17 .333-17     .665-08
   24.00    10.00       .62     .190+16     .573-18 .140-17     .279-08
   24.00    20.00      1.28     .782+16     .266-18 .657-18     .131-08
   24.00    40.00      2.70     .329+17     .115-18 .301-18     .603-09
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Down-current Distribution for NORMAL OPERATION, Continuous Release

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 CURRENT   PLUME     HALF      VOLUME       CONCENTRATION  AVE. SPEC.
VELOCITY  LENGTH    WIDTH    IN PLUME         ISO-    AVE.   ACTIVITY
  NM/DAY      NM       NM       CC          UCI/CC  UCI/CC     UCI/GM

HALF LIFE   .109+03 DAYS               TE127M
RELEASE RATE   .390-04 CURIES PER YEAR
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .000    GRAMS PER CC
MAXIMUM PERMISSIBLE                                  .950-06       .350+00
DAUGHTER OF PREVIOUS RADIONUCLIDE, DECAY FRACTION =   .1600

     .50     1.00      .06     .186+14      .402-14 .809-14      .000
     .50     2.00      .12     .747+14      .199-14 .427-14      .000
     .50     4.00      .25     .302+15      .968-15 .217-14      .000
     .50    10.00      .64     .194+16      .359-15 .897-15      .000
     .50    20.00     1.33     .811+16      .158-15 .411-15      .000
     .50    40.00     2.87     .350+17      .612-16 .179-15      .000
    4.00     1.00      .06     .185+14      .508-15 .102-14      .000
    4.00     2.00      .12     .741+14      .254-15 .540-15      .000
    4.00     4.00      .24     .297+15      .126-15 .277-15      .000
    4.00    10.00      .61     .186+16      .501-16 .118-15      .000
    4.00    20.00     1.23     .749+16      .247-16 .575-16      .000
    4.00    40.00     2.49     .303+17      .119-16 .280-16      .000
   24.00     1.00      .06     .185+14      .848-16 .170-15      .000
   24.00     2.00      .12     .740+14      .424-16 .901-16      .000
   24.00     4.00      .24     .296+15      .212-16 .469-16      .000
   24.00    10.00      .61     .185+16      .846-17 .199-16      .000
   24.00    20.00     1.22     .741+16      .422-17 .972-17      .000
   24.00    40.00     2.44     .297+17      .210-17 .480-17      .000

HALF LIFE   .392+00 DAYS               TE 127
RELEASE RATE   .165-03 CURIES PER YEAR
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .000    GRAMS PER CC
MAXIMUM PERMISSIBLE                                  .320-05       .230+02
DAUGHTER OF PREVIOUS RADIONUCLIDE, DECAY FRACTION =  1.0000

     .50     1.00      .08     .232+14      .460-14 .130-13      .000
     .50     2.00      .14     .828+14      .207-14 .604-14      .000
     .50     4.00      .27     .325+15      .988-15 .268-14      .000
     .50    10.00      .68     .207+16      .361-15 .988-15      .000
     .50    20.00     1.41     .857+16      .159-15 .436-15      .000
     .50    40.00     3.01     .367+17      .615-16 .186-15      .000
    4.00     1.00      .07     .207+14      .158-14 .367-14      .000
    4.00     2.00      .15     .891+14      .603-15 .169-14      .000
    4.00     4.00      .31     .382+15      .203-15 .703-15      .000
    4.00    10.00      .73     .223+16      .544-16 .227-15      .000
    4.00    20.00     1.34     .814+16      .255-16 .912-16      .000
    4.00    40.00     2.67     .326+17      .121-16 .369-16      .000
   24.00     1.00      .06     .189+14      .340-15 .698-15      .000
   24.00     2.00      .13     .772+14      .161-15 .360-15      .000
   24.00     4.00      .26     .321+15      .726-16 .175-15      .000
   24.00    10.00      .72     .218+16      .219-16 .660-16      .000
   24.00    20.00     1.54     .941+16      .755-17 .266-16      .000
   24.00    40.00     3.11     .380+17      .257-17 .104-16      .000
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 CURRENT   PLUME     HALF      VOLUME       CONCENTRATION  AVE. SPEC.
VELOCITY  LENGTH    WIDTH    IN PLUME         ISO-    AVE.   ACTIVITY
  NM/DAY      NM       NM       CC          UCI/CC  UCI/CC     UCI/GM

HALF LIFE   .341+02 DAYS               TE129M
RELEASE RATE   .205-05 CURIES PER YEAR
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .000    GRAMS PER CC
MAXIMUM PERMISSIBLE                                  .320-06       .180+00

     .50     1.00      .06     .188+14      .205-15 .419-15      .000
     .50     2.00      .13     .763+14      .987-16 .218-15      .000
     .50     4.00      .26     .314+15      .455-16 .107-15      .000
     .50    10.00      .70     .213+16      .143-16 .413-16      .000
     .50    20.00     1.55     .948+16      .475-17 .166-16      .000
     .50    40.00     3.66     .447+17      .105-17 .581-17      .000
    4.00     1.00      .06     .185+14      .266-16 .534-16      .000
    4.00     2.00      .12     .743+14      .132-16 .283-16      .000
    4.00     4.00      .24     .298+15      .655-17 .148-16      .000
    4.00    10.00      .62     .189+16      .254-17 .612-17      .000
    4.00    20.00     1.26     .769+16      .121-17 .292-17      .000
    4.00    40.00     2.61     .319+17      .546-18 .137-17      .000
   24.00     1.00      .06     .185+14      .445-17 .891-17      .000
   24.00     2.00      .12     .740+14      .223-17 .473-17      .000
   24.00     4.00      .24     .296+15      .111-17 .243-17      .000
   24.00    10.00      .61     .186+16      .442-18 .104-17      .000
   24.00    20.00     1.22     .745+16      .219-18 .508-18      .000
   24.00    40.00     2.46     .300+17      .108-18 .249-18      .000

HALF LIFE   .477-01 DAYS               TE 129
RELEASE RATE   .666-03 CURIES PER YEAR
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .000    GRAMS PER CC
MAXIMUM PERMISSIBLE                                  .130-04       .640+02
DAUGHTER OF PREVIOUS RADIONUCLIDE, DECAY FRACTION =   .6400

     .50     1.00      .06     .188+14      .132-15 .269-15      .000
     .50     2.00      .13     .763+14      .632-16 .140-15      .000
     .50     4.00      .26     .314+15      .291-16 .689-16      .000
     .50    10.00      .70     .213+16      .914-17 .265-16      .000
     .50    20.00     1.55     .948+16      .304-17 .107-16      .000
     .50    40.00     3.66     .447+17      .675-18 .373-17      .000
    4.00     1.00      .12     .358+14      .247-15 .286-14      .000
    4.00     2.00      .25     .154+15      .115-16 .762-15      .000
    4.00     4.00      .26     .319+15      .420-17 .373-15      .000
    4.00    10.00      .62     .189+16      .163-17 .655-16      .000
    4.00    20.00     1.26     .769+16      .774-18 .170-16      .000
    4.00    40.00     2.61     .319+17      .350-18 .452-17      .000
   24.00     1.00      .07     .225+14      .792-15 .214-14      .000
   24.00     2.00      .17     .103+15      .217-15 .861-15      .000
   24.00     4.00      .41     .502+15      .328-16 .276-15      .000
   24.00    10.00     1.31     .401+16      .623-18 .442-16      .000
   24.00    20.00     1.52     .929+16      .141-18 .215-16      .000
   24.00    40.00     2.46     .300+17      .691-19 .672-17      .000
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Down-current Distribution for NORMAL OPERATION, Continuous Release

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 CURRENT   PLUME     HALF      VOLUME      CONCENTRATION   AVE. SPEC.
VELOCITY  LENGTH    WIDTH    IN PLUME        ISO-     AVE.    ACTIVITY
  NM/DAY      NM       NM       CC         UCI/CC   UCI/CC      UCI/GM

HALF LIFE   .620+10 DAYS                 I 129
RELEASE RATE   .127-08 CURIES PER YEAR
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .600-07 GRAMS PER CC
MAXIMUM PERMISSIBLE
                                               .630-09        .750+01
DAUGHTER OF PREVIOUS RADIONUCLIDE, DECAY FRACTION =  1.0000

     .50     1.00      .06     .185+14     .133-18  .265-18     .442-11
     .50     2.00      .12     .740+14     .663-19  .141-18     .235-11
     .50     4.00      .24     .296+15     .331-19  .725-19     .121-11
     .50    10.00      .61     .185+16     .133-19  .311-19     .518-12
     .50    20.00     1.21     .740+16     .663-20  .152-19     .254-12
     .50    40.00     2.43     .296+17     .331-20  .754-20     .126-12
    4.00     1.00      .06     .185+14     .166-19  .331-19     .552-12
    4.00     2.00      .12     .740+14     .829-20  .176-19     .293-12
    4.00     4.00      .24     .296+15     .414-20  .906-20     .151-12
    4.00    10.00      .61     .185+16     .166-20  .389-20     .648-13
    4.00    20.00     1.21     .740+16     .829-21  .190-20     .317-13
    4.00    40.00     2.43     .296+17     .414-21  .942-21     .157-13
   24.00     1.00      .06     .185+14     .276-20  .552-20     .921-13
   24.00     2.00      .12     .740+14     .138-20  .293-20     .489-13
   24.00     4.00      .24     .296+15     .691-21  .151-20     .252-13
   24.00    10.00      .61     .185+16     .276-21  .648-21     .108-13
   24.00    20.00     1.21     .740+16     .138-21  .317-21     .529-14
   24.00    40.00     2.43     .296+17     .691-22  .157-21     .262-14
HALF LIFE   .125+01 DAYS                TE131M
RELEASE RATE   .655-03 CURIES PER YEAR
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .000     GRAMS PER CC
MAXIMUM PERMISSIBLE
                                               .630-06        .220+01

     .50     1.00      .08     .253+14     .226-13  .786-13     .000
     .50     2.00      .20     .123+15     .372-14  .266-13     .000
     .50     4.00      .51     .627+15     .203-15  .679-14     .000
     .50    10.00     1.89     .577+16     .105-18  .828-15     .000
     .50    20.00     5.21     .318+17     .800-24  .150-15     .000
     .50    40.00    14.54     .177+18     .936-34  .270-16     .000
    4.00     1.00      .06     .195+14     .744-14  .160-13     .000
    4.00     2.00      .13     .817+14     .324-14  .787-14     .000
    4.00     4.00      .29     .355+15     .123-14  .353-14     .000
    4.00    10.00      .88     .268+16     .214-15  .109-14     .000
    4.00    20.00     2.16     .132+17     .267-16  .317-15     .000
    4.00    40.00     5.62     .686+17     .836-18  .723-16     .000
   24.00     1.00      .06     .187+14     .139-14  .282-14     .000
   24.00     2.00      .12     .753+14     .680-15  .148-14     .000
   24.00     4.00      .25     .307+15     .325-15  .742-15     .000
   24.00    10.00      .66     .201+16     .113-15  .299-15     .000
   24.00    20.00     1.42     .864+16     .449-16  .130-15     .000
   24.00    40.00     3.19     .389+17     .141-16  .519-16     .000
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 CURRENT   PLUME     HALF      VOLUME      CONCENTRATION   AVE. SPEC.
VELOCITY  LENGTH    WIDTH    IN PLUME        ISO-     AVE.    ACTIVITY
  NM/DAY      NM       NM       CC         UCI/CC   UCI/CC      UCI/GM

HALF LIFE   .805+01 DAYS                 I 131
RELEASE RATE   .108+00 CURIES PER YEAR
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .600-07 GRAMS PER CC
MAXIMUM PERMISSIBLE
                                               .320-08        .320+02
DAUGHTER OF PREVIOUS RADIONUCLIDE, DECAY FRACTION =  1.0000

     .50     1.00      .06     .197+14     .950-11  .207-10     .345-03
     .50     2.00      .14     .834+14     .400-11  .100-10     .167-03
     .50     4.00      .30     .368+15     .142-11  .437-11     .729-04
     .50    10.00      .93     .284+16     .202-12  .127-11     .212-04
     .50    20.00     2.34     .143+17     .180-13  .341-12     .569-05
     .50    40.00     6.15     .750+17     .288-15  .723-13     .120-05
    4.00     1.00      .06     .187+14     .138-11  .279-11     .465-04
    4.00     2.00      .12     .752+14     .675-12  .146-11     .244-04
    4.00     4.00      .25     .306+15     .323-12  .737-12     .123-04
    4.00    10.00      .66     .200+16     .114-12  .298-12     .496-05
    4.00    20.00     1.40     .856+16     .459-13  .131-12     .218-05
    4.00    40.00     3.14     .383+17     .149-13  .528-13     .880-06
   24.00     1.00      .06     .185+14     .234-12  .469-12     .782-05
   24.00     2.00      .12     .742+14     .117-12  .249-12     .414-05
   24.00     4.00      .24     .298+15     .579-13  .127-12     .212-05
   24.00    10.00      .61     .188+16     .227-13  .541-13     .902-06
   24.00    20.00     1.25     .760+16     .109-13  .260-13     .433-06
   24.00    40.00     2.56     .312+17     .509-14  .124-13     .207-06
HALF LIFE   .324+01 DAYS                TE 132
RELEASE RATE   .864-02 CURIES PER YEAR
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .000     GRAMS PER CC
MAXIMUM PERMISSIBLE
                                               .320-06        .730+00

     .50     1.00      .07     .214+14     .588-12  .146-11     .000
     .50     2.00      .16     .957+14     .192-12  .628-12     .000
     .50     4.00      .37     .453+15     .407-13  .224-12     .000
     .50    10.00     1.27     .387+16     .125-14  .448-13     .000
     .50    20.00     3.37     .206+17     .868-17  .894-14     .000
     .50    40.00     9.23     .113+18     .835-21  .164-14     .000
    4.00     1.00      .06     .189+14     .107-12  .220-12     .000
    4.00     2.00      .13     .770+14     .507-13  .113-12     .000
    4.00     4.00      .26     .320+15     .228-13  .551-13     .000
    4.00    10.00      .72     .221+16     .661-14  .206-13     .000
    4.00    20.00     1.65     .100+17     .193-14  .786-14     .000
    4.00    40.00     3.97     .485+17     .332-15  .252-14     .000
   24.00     1.00      .06     .186+14     .186-13  .379-13     .000
   24.00     2.00      .12     .745+14     .923-14  .198-13     .000
   24.00     4.00      .25     .300+15     .453-14  .101-13     .000
   24.00    10.00      .63     .191+16     .172-14  .422-14     .000
   24.00    20.00     1.30     .790+16     .786-15  .197-14     .000
   24.00    40.00     2.75     .335+17     .329-15  .891-15     .000
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Down-current Distribution for NORMAL OPERATION, Continuous Release

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 CURRENT   PLUME    HALF      VOLUME      CONCENTRATION  AVE. SPEC.
VELOCITY  LENGTH   WIDTH    IN PLUME        ISO-    AVE.   ACTIVITY
  NM/DAY      NM      NM       CC         UCI/CC  UCI/CC     UCI/GM

HALF LIFE   .942-01 DAYS                 I 132
RELEASE RATE   .254+00 CURIES PER YEAR
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .600-07 GRAMS PER CC
MAXIMUM PERMISSIBLE                              .000          .110+04
DAUGHTER OF PREVIOUS RADIONUCLIDE, DECAY FRACTION =  1.0000

     .50     1.00      .07    .215+14    .606-12 .153-11     .255-09
     .50     2.00      .16    .957+14    .197-12 .655-12     .109-09
     .50     4.00      .37    .453+15    .420-13 .233-12     .388-05
     .50    10.00     1.27    .387+16    .129-14 .469-13     .773-06
     .50    20.00     3.37    .206+17    .894-17 .924-14     .154-06
     .50    40.00     9.23    .113+18    .860-21 .169-14     .282-07
    4.00     1.00      .09    .278+14    .618-12 .278-11     .963-09
    4.00     2.00      .20    .124+15    .926-13 .901-12     .150-09
    4.00     4.00      .32    .391+15    .240-13 .325-12     .591-05
    4.00    10.00      .72    .221+16    .680-14 .701-13     .117-05
    4.00    20.00     1.65    .100+17    .199-14 .188-13     .314-06
    4.00    40.00     3.97    .985+17    .342-15 .983-14     .805-07
   24.00     1.00      .07    .205+14    .412-12 .953-12     .159-09
   24.00     2.00      .15    .893+14    .154-12 .937-12     .728-05
   24.00     4.00      .33    .406+15    .438-13 .173-12     .289-05
   24.00    10.00     1.00    .306+16    .426-14 .438-13     .730-06
   24.00    20.00     1.76    .108+17    .868-15 .143-13     .238-06
   24.00    40.00     2.79    .340+17    .339-15 .494-14     .823-07

HALF LIFE   .846+00 DAYS                 I 133
RELEASE RATE   .140+00 CURIES PER YEAR
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .600-07 GRAMS PER CC
MAXIMUM PERMISSIBLE                              .110-07       .120+03

     .50     1.00      .09    .280+14    .284-11 .129-10     .215-03
     .50     2.00      .23    .140+15    .276-12 .382-11     .637-04
     .50     4.00      .60    .735+15    .521-14 .842-12     .140-04
     .50    10.00     2.26    .690+16    .112-18 .921-13     .153-05
     .50    20.00     6.28    .383+17    .430-24 .166-13     .276-06
     .50    40.00    17.59    .215+18    .000    .296-14     .493-07
    4.00     1.00      .07    .199+14    .149-11 .330-11     .550-04
    4.00     2.00      .14    .851+14    .607-12 .157-11     .262-04
    4.00     4.00      .31    .380+15    .201-12 .666-12     .111-04
    4.00    10.00      .98    .299+16    .236-13 .183-12     .305-05
    4.00    20.00     2.49    .152+17    .152-14 .460-13     .767-06
    4.00    40.00     6.62    .808+17    .127-16 .929-14     .155-06
   24.00     1.00      .06    .187+14    .294-12 .599-12     .998-05
   24.00     2.00      .12    .760+14    .142-12 .312-12     .520-05
   24.00     4.00      .26    .311+15    .664-13 .155-12     .258-05
   24.00    10.00      .68    .208+16    .216-13 .606-13     .101-05
   24.00    20.00     1.50    .917+16    .769-14 .251-13     .418-06
   24.00    40.00     3.49    .426+17    .194-14 .918-14     .153-06
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 CURRENT   PLUME    HALF      VOLUME      CONCENTRATION  AVE. SPEC.
VELOCITY  LENGTH   WIDTH    IN PLUME        ISO-    AVE.   ACTIVITY
  NM/DAY      NM      NM       CC         UCI/CC  UCI/CC     UCI/GM

HALF LIFE   .292-01 DAYS                 TE 134
RELEASE RATE   .567-03 CURIES PER YEAR
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .000    GRAMS PER CC
MAXIMUM PERMISSIBLE                              .000          .000

     .50     1.00      .38    .115+15    .144-33 .584-23     .000
     .50     2.00     1.06    .644+15    .000    .104-23     .000
     .50     4.00     2.98    .363+16    .000    .184-24     .000
     .50    10.00    11.74    .358+17    .000    .187-25     .000
     .50    20.00    33.18    .202+18    .000    .330-26     .000
     .50    40.00    93.83    .114+19    .000    .584-27     .000
    4.00     1.00      .14    .441+14    .196-16 .762-15     .000
    4.00     2.00      .39    .238+15    .260-19 .149-15     .000
    4.00     4.00     1.08    .131+16    .912-25 .270-16     .000
    4.00    10.00     4.19    .128+17    .000    .278-17     .000
    4.00    20.00    11.79    .719+17    .000    .493-18     .000
    4.00    40.00    33.25    .906+18    .000    .875-19     .000
   24.00     1.00      .08    .247+14    .459-15 .160-14     .000
   24.00     2.00      .19    .118+15    .853-16 .829-15     .000
   24.00     4.00      .49    .600+15    .590-17 .141-15     .000
   24.00    10.00     1.80    .548+16    .626-20 .181-16     .000
   24.00    20.00     4.94    .301+17    .159-24 .329-17     .000
   24.00    40.00    13.75    .168+18    .209-33 .590-18     .000

HALF LIFE   .361-01 DAYS                 I 134
RELEASE RATE   .134-01 CURIES PER YEAR
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .600-07 GRAMS PER CC
MAXIMUM PERMISSIBLE                              .160-06       .190+04
DAUGHTER OF PREVIOUS RADIONUCLIDE, DECAY FRACTION =  1.0000

     .50     1.00      .34    .103+15    .349-28 .152-19     .253-12
     .50     2.00      .95    .580+15    .000    .270-20     .450-13
     .50     4.00      .00    .000       .000    .000        .000
     .50    10.00      .00    .000       .000    .000        .000
     .50    20.00      .00    .000       .000    .000        .000
     .50    40.00      .00    .000       .000    .000        .000
    4.00     1.00      .13    .902+14    .162-14 .342-13     .570-06
    4.00     2.00      .35    .216+15    .688-17 .703-14     .117-06
    4.00     4.00      .97    .119+16    .237-21 .128-14     .213-07
    4.00    10.00     3.78    .115+17    .296-34 .132-15     .220-08
    4.00    20.00      .00    .000       .000    .000        .000
    4.00    40.00      .00    .000       .000    .000        .000
   24.00     1.00      .08    .235+14    .138-13 .397-13     .662-06
   24.00     2.00      .18    .110+15    .3[illegible]1-14 .150-13     .250-06
   24.00     4.00      .45    .551+15    .325-15 .937-14     .729-07
   24.00    10.00     1.63    .498+16    .113-17 .629-15     .105-07
   24.00    20.00     4.47    .273+17    .193-21 .11[illegible]-15     .192-08
   24.00    40.00    12.41    .151+18    .109-28 .208-16     .346-09
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Down-current Distribution for NORMAL OPERATION, Continuous Release

HALF LIFE .748+03 DAYS CS 134
RELEASE RATE .464+00 CURIES PER YEAR
NATURAL CONCENTRATION OF CARRIER IN SEAWATER .380-03 GRAMS PER CC
MAXIMUM PERMISSIBLE .900-06 .150-01

CURRENT VELOCITY NM/DAY	PLUME LENGTH NM	HALF WIDTH NM	VOLUME IN PLUME CC	CONCENTRATION		AVE. SPEC. ACTIVITY UCI/GM
				ISO- UCI/CC	AVE. UCI/CC	
.50	1.00	.06	.185+14	.484-10	.968-10	.255-06
.50	2.00	.12	.741+14	.241-10	.519-10	.135-06
.50	4.00	.24	.297+15	.120-10	.264-10	.694-07
.50	10.00	.61	.106+16	.476-11	.113-10	.296-07
.50	20.00	1.23	.751+16	.233-11	.546-11	.144-07
.50	40.00	2.50	.304+17	.112-11	.265-11	.697-08
4.00	1.00	.06	.185+14	.605-11	.121-10	.319-07
4.00	2.00	.12	.740+14	.303-11	.643-11	.169-07
4.00	4.00	.24	.296+15	.151-11	.331-11	.871-08
4.00	10.00	.61	.185+16	.604-12	.142-11	.373-08
4.00	20.00	1.22	.741+16	.301-12	.694-12	.183-08
4.00	40.00	2.43	.297+17	.150-12	.343-12	.901-09
24.00	1.00	.06	.185+14	.101-11	.202-11	.531-08
24.00	2.00	.12	.740+14	.505-12	.107-11	.282-08
24.00	4.00	.24	.296+15	.252-12	.552-12	.145-08
24.00	10.00	.61	.185+16	.101-12	.237-12	.623-09
24.00	20.00	1.21	.740+16	.504-13	.116-12	.305-09
24.00	40.00	2.43	.296+17	.252-13	.573-13	.151-09

HALF LIFE .278+00 DAYS I 135
RELEASE RATE .619-01 CURIES PER YEAR
NATURAL CONCENTRATION OF CARRIER IN SEAWATER .600-07 GRAMS PER CC
MAXIMUM PERMISSIBLE .320-07 .370+03

CURRENT VELOCITY NM/DAY	PLUME LENGTH NM	HALF WIDTH NM	VOLUME IN PLUME CC	CONCENTRATION ISO- UCI/CC	AVE. UCI/CC	AVE. SPEC. ACTIVITY UCI/GM
.50	1.00	.13	.911+14	.442-13	.107-11	.178-04
.50	2.00	.36	.220+15	.151-15	.217-12	.362-05
.50	4.00	.99	.121+16	.353-20	.396-13	.660-06
.50	10.00	3.85	.117+17	.144-33	.408-14	.680-07
.50	20.00	10.82	.660+17	.000	.726-15	.121-07
.50	40.00	30.49	.372+18	.000	.129-15	.215-08
4.00	1.00	.07	.226+14	.433-12	.118-11	.197-04
4.00	2.00	.17	.109+15	.116-12	.472-12	.786-05
4.00	4.00	.42	.509+15	.167-13	.149-12	.249-05
4.00	10.00	1.47	.450+16	.159-15	.244-13	.406-06
4.00	20.00	3.99	.243+17	.156-18	.457-14	.762-07
4.00	40.00	11.02	.134+18	.301-24	.827-15	.138-07
24.00	1.00	.06	.192+14	.121-12	.256-12	.426-05
24.00	2.00	.13	.798+14	.547-13	.128-12	.214-05
24.00	4.00	.28	.341+15	.222-13	.595-13	.992-06
24.00	10.00	.82	.249+16	.476-14	.198-13	.330-06
24.00	20.00	1.97	.120+17	.843-15	.633-14	.105-06
24.00	40.00	5.01	.612+17	.528-16	.160-14	.267-07

HALF LIFE .137+02 DAYS CS 136
RELEASE RATE .300-01 CURIES PER YEAR
NATURAL CONCENTRATION OF CARRIER IN SEAWATER .380-03 GRAMS PER CC
MAXIMUM PERMISSIBLE .600-05 .190+00

CURRENT VELOCITY NM/DAY	PLUME LENGTH NM	HALF WIDTH NM	VOLUME IN PLUME CC	CONCENTRATION		AVE. SPEC. ACTIVITY UCI/GM
				ISO- UCI/CC	AVE. UCI/CC	
.50	1.00	.06	.192+14	.283-11	.596-11	.157-07
.50	2.00	.13	.797+14	.128-11	.300-11	.788-08
.50	4.00	.28	.340+15	.522-12	.139-11	.366-08
.50	10.00	.81	.248+16	.114-12	.465-12	.122-08
.50	20.00	1.95	.119+17	.207-13	.150-12	.395-09
.50	40.00	4.96	.606+17	.137-14	.384-13	.101-09
4.00	1.00	.06	.186+14	.387-12	.778-12	.205-08
4.00	2.00	.12	.747+14	.191-12	.410-12	.108-08
4.00	4.00	.25	.302+15	.930-13	.206-12	.544-09
4.00	10.00	.64	.194+16	.345-13	.863-13	.227-09
4.00	20.00	1.33	.810+16	.152-13	.396-13	.104-09
4.00	40.00	2.87	.350+17	.590-14	.173-13	.454-10
24.00	1.00	.06	.185+14	.651-13	.130-12	.343-09
24.00	2.00	.12	.741+14	.326-13	.692-13	.182-09
24.00	4.00	.24	.297+15	.162-13	.355-13	.935-10
24.00	10.00	.61	.187+16	.639-14	.151-13	.398-10
24.00	20.00	1.23	.752+16	.313-14	.733-14	.193-10
24.00	40.00	2.51	.306+17	.150-14	.355-14	.934-11

HALF LIFE .109+05 DAYS CS 137
RELEASE RATE .443+01 CURIES PER YEAR
NATURAL CONCENTRATION OF CARRIER IN SEAWATER .380-03 GRAMS PER CC
MAXIMUM PERMISSIBLE .200-05 .210-01

CURRENT VELOCITY NM/DAY	PLUME LENGTH NM	HALF WIDTH NM	VOLUME IN PLUME CC	CONCENTRATION ISO- UCI/CC	AVE. UCI/CC	AVE. SPEC. ACTIVITY UCI/GM
.50	1.00	.06	.185+14	.962-09	.925-09	.243-05
.50	2.00	.12	.740+14	.231-09	.491-09	.129-05
.50	4.00	.24	.296+15	.116-09	.253-09	.665-06
.50	10.00	.61	.185+16	.462-10	.108-09	.285-06
.50	20.00	1.21	.741+16	.231-10	.531-10	.140-06
.50	40.00	2.43	.297+17	.115-10	.262-10	.690-07
4.00	1.00	.06	.185+14	.578-10	.116-09	.304-06
4.00	2.00	.12	.740+14	.289-10	.619-10	.162-06
4.00	4.00	.24	.296+15	.145-10	.316-10	.832-07
4.00	10.00	.61	.185+16	.578-11	.136-10	.357-07
4.00	20.00	1.21	.740+16	.289-11	.664-11	.175-07
4.00	40.00	2.43	.296+17	.144-11	.329-11	.865-08
24.00	1.00	.06	.185+14	.964-11	.193-10	.507-07
24.00	2.00	.12	.740+14	.482-11	.102-10	.269-07
24.00	4.00	.24	.296+15	.241-11	.527-11	.139-07
24.00	10.00	.61	.185+16	.963-12	.226-11	.595-08
24.00	20.00	1.21	.740+16	.482-12	.111-11	.291-08
24.00	40.00	2.43	.296+17	.241-12	.548-12	.144-08

Down-current Distribution for NORMAL OPERATION, Continuous Release

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 CURRENT   PLUME     HALF      VOLUME       CONCENTRATION  AVE. SPEC.
VELOCITY  LENGTH    WIDTH    IN PLUME        ISO-     AVE.   ACTIVITY
  NM/DAY      NM       NM       CC         UCI/CC   UCI/CC     UCI/GM

HALF LIFE   .224-01 DAYS                 CS 138
RELEASE RATE   .123+00 CURIES PER YEAR
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .380-03 GRAMS PER CC
MAXIMUM PERMISSIBLE                                  .000          .000

     .50     1.00      .43     .130+15    .172-37  .991-24    .248-20
     .50     2.00     1.20     .734+15    .000     .167-24    .440-21
     .50     4.00     3.40     .414+16    .000     .296-25    .780-22
     .50    10.00    13.40     .409+17    .000     .300-26    .790-23
     .50    20.00    37.88     .231+18    .000     .531-27    .140-23
     .50    40.00   107.12     .131+19    .000     .939-28    .247-24
    4.00     1.00      .16     .493+14    .702-15  .672-13    .177-09
    4.00     2.00      .44     .269+15    .154-18  .126-13    .332-10
    4.00     4.00     1.22     .149+16    .147-25  .227-14    .598-11
    4.00    10.00     4.77     .146+17    .000     .233-15    .612-12
    4.00    20.00    13.44     .820+17    .000     .413-16    .109-12
    4.00    40.00    37.94     .463+18    .000     .731-17    .192-13
   24.00     1.00      .09     .263+14    .737-13  .281-12    .739-09
   24.00     2.00      .21     .129+15    .102-13  .906-13    .239-09
   24.00     4.00      .55     .666+15    .385-15  .218-13    .573-10
   24.00    10.00     2.03     .618+16    .675-19  .252-14    .663-11
   24.00    20.00     5.60     .341+17    .851-25  .456-15    .120-11
   24.00    40.00    15.45     .191+18    .270-36  .816-16    .215-12

HALF LIFE   .128+02 DAYS                 BA 140
RELEASE RATE   .171-03 CURIES PER YEAR
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .300-07 GRAMS PER CC
MAXIMUM PERMISSIBLE                               .320-05       .150+03

     .50     1.00      .06     .193+14    .160-13  .338-13    .113-05
     .50     2.00      .13     .801+14    .719-14  .170-13    .565-06
     .50     4.00      .28     .343+15    .289-14  .782-14    .261-06
     .50    10.00      .83     .252+16    .605-15  .258-14    .859-07
     .50    20.00     2.00     .122+17    .102-15  .813-15    .271-07
     .50    40.00     5.09     .622+17    .587-17  .203-15    .676-08
    4.00     1.00      .06     .186+14    .220-14  .443-14    .148-06
    4.00     2.00      .12     .748+14    .109-14  .234-14    .779-07
    4.00     4.00      .25     .302+15    .528-15  .119-14    .395-07
    4.00    10.00      .64     .195+16    .195-15  .490-15    .163-07
    4.00    20.00     1.34     .815+16    .851-16  .224-15    .745-08
    4.00    40.00     2.90     .353+17    .325-16  .968-16    .323-08
   24.00     1.00      .06     .185+14    .371-15  .743-15    .248-07
   24.00     2.00      .12     .741+14    .185-15  .394-15    .131-07
   24.00     4.00      .24     .297+15    .921-16  .202-15    .675-08
   24.00    10.00      .61     .187+16    .364-16  .862-16    .287-08
   24.00    20.00     1.23     .753+16    .178-16  .417-16    .139-08
   24.00    40.00     2.51     .306+17    .850-17  .202-16    .672-09
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 CURRENT   PLUME     HALF      VOLUME       CONCENTRATION  AVE. SPEC.
VELOCITY  LENGTH    WIDTH    IN PLUME        ISO-     AVE.   ACTIVITY
  NM/DAY      NM       NM       CC         UCI/CC   UCI/CC     UCI/GM

HALF LIFE   .168+01 DAYS                 LA 140
RELEASE RATE   .165-03 CURIES PER YEAR
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .300-09 GRAMS PER CC
MAXIMUM PERMISSIBLE                               .380-06       .480+04
DAUGHTER OF PREVIOUS RADIONUCLIDF, DECAY FRACTION =  1.0000

     .50     1.00      .06     .188+14    .170-13  .345-13    .115-03
     .50     2.00      .13     .779+14    .795-14  .178-13    .593-04
     .50     4.00      .28     .338+15    .330-14  .843-14    .281-04
     .50    10.00      .82     .252+16    .696-15  .286-14    .954-05
     .50    20.00     2.00     .122+17    .118-15  .914-15    .305-05
     .50    40.00     5.09     .622+17    .675-17  .229-15    .763-06
    4.00     1.00      .06     .185+14    .216-14  .431-14    .144-04
    4.00     2.00      .12     .739+14    .108-14  .229-14    .765-05
    4.00     4.00      .24     .297+15    .540-15  .118-14    .393-05
    4.00    10.00      .62     .189+16    .210-15  .501-15    .167-05
    4.00    20.00     1.30     .796+16    .953-16  .235-15    .784-06
    4.00    40.00     2.87     .350+17    .372-16  .105-15    .349-06
   24.00     1.00      .06     .185+14    .359-15  .718-15    .239-05
   24.00     2.00      .12     .740+14    .180-15  .382-15    .127-05
   24.00     4.00      .24     .296+15    .899-16  .196-15    .655-06
   24.00    10.00      .61     .185+16    .360-16  .843-16    .281-06
   24.00    20.00     1.21     .740+16    .180-16  .413-16    .138-06
   24.00    40.00     2.95     .299+17    .891-17  .204-16    .679-07

HALF LIFE   .325+02 DAYS                 CE 141
RELEASE RATE   .150-03 CURIES PER YEAR
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .300-09 GRAMS PER CC
MAXIMUM PERMISSIBLE                               .170-05       .120+04

     .50     1.00      .06     .188+14    .150-13  .307-13    .102-03
     .50     2.00      .13     .764+14    .719-14  .159-13    .530-04
     .50     4.00      .26     .315+15    .330-14  .783-14    .261-04
     .50    10.00      .70     .214+16    .102-14  .300-14    .999-05
     .50    20.00     1.57     .957+16    .334-15  .120-14    .399-05
     .50    40.00     3.71     .453+17    .711-16  .412-15    .137-05
    4.00     1.00      .06     .185+14    .195-14  .390-14    .130-04
    4.00     2.00      .12     .743+14    .968-15  .207-14    .689-05
    4.00     4.00      .24     .298+15    .479-15  .106-14    .353-05
    4.00    10.00      .62     .189+16    .186-15  .447-15    .149-05
    4.00    20.00     1.26     .770+16    .880-16  .213-15    .709-06
    4.00    40.00     2.62     .320+17    .395-16  .997-16    .332-06
   24.00     1.00      .06     .185+14    .326-15  .652-15    .217-05
   24.00     2.00      .12     .740+14    .163-15  .346-15    .115-05
   24.00     4.00      .24     .296+15    .813-16  .178-15    .594-06
   24.00    10.00      .61     .186+16    .323-16  .762-16    .254-06
   24.00    20.00     1.22     .745+16    .160-16  .371-16    .124-06
   24.00    40.00     2.46     .300+17    .787-17  .182-16    .607-07
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Down-current Distribution for NORMAL OPERATION, Continuous Release

HALF LIFE .137+01 DAYS CE 143
RELEASE RATE .143-03 CURIES PER YEAR
NATURAL CONCENTRATION OF CARRIER IN SEAWATER .300-09 GRAMS PER CC
MAXIMUM PERMISSIBLE .760-06 .680+09

CURRENT VELOCITY NM/DAY	PLUME LENGTH NM	HALF WIDTH NM	VOLUME IN PLUME CC	CONCENTRATION ISO- UCI/CC	CONCENTRATION AVE. UCI/CC	AVE. SPEC. ACTIVITY UCI/GM
.50	1.00	.08	.248+14	.545-14	.180-13	.601-04
.50	2.00	.20	.119+15	.994-15	.631-14	.210-04
.50	4.00	.50	.605+15	.662-16	.167-14	.556-05
.50	10.00	1.81	.553+16	.626-19	.212-15	.706-06
.50	20.00	4.98	.304+17	.131-23	.386-16	.129-06
.50	40.00	13.88	.169+18	.115-32	.692-17	.231-07
4.00	1.00	.06	.194+14	.165-14	.350-14	.117-04
4.00	2.00	.13	.810+14	.725-15	.174-14	.580-05
4.00	4.00	.29	.350+15	.282-15	.790-15	.263-05
4.00	10.00	.86	.261+16	.529-16	.251-15	.836-06
4.00	20.00	2.10	.128+17	.751-17	.753-16	.251-06
4.00	40.00	5.41	.660+17	.302-18	.177-16	.591-07
24.00	1.00	.06	.187+14	.305-15	.616-15	.205-05
24.00	2.00	.12	.752+14	.149-15	.323-15	.108-05
24.00	4.00	.25	.306+15	.715-16	.163-15	.542-06
24.00	10.00	.65	.200+16	.252-16	.659-16	.220-06
24.00	20.00	1.40	.854+16	.102-16	.290-16	.966-07
24.00	40.00	3.13	.381+17	.336-17	.118-16	.392-07

HALF LIFE .136+02 DAYS PR 143
RELEASE RATE .149-03 CURIES PER YEAR
NATURAL CONCENTRATION OF CARRIER IN SEAWATER .300-09 GRAMS PER CC
MAXIMUM PERMISSIBLE .950-07 .180+09
DAUGHTER OF PREVIOUS RADIONUCLIDE, DECAY FRACTION = 1.0000

.50	1.00	.06	.189+14	.150-13	.307-13	.102-03
.50	2.00	.13	.785+14	.692-14	.157-13	.523-04
.50	4.00	.28	.338+15	.286-14	.740-14	.247-04
.50	10.00	.81	.248+16	.622-15	.251-14	.837-05
.50	20.00	1.96	.119+17	.112-15	.812-15	.271-05
.50	40.00	4.98	.607+17	.729-17	.208-15	.692-06
4.00	1.00	.06	.185+14	.194-14	.389-14	.130-04
4.00	2.00	.12	.742+14	.969-15	.206-14	.687-05
4.00	4.00	.24	.298+15	.480-15	.106-14	.352-05
4.00	10.00	.63	.191+16	.184-15	.445-15	.148-05
4.00	20.00	1.31	.801+16	.826-16	.208-15	.692-06
4.00	40.00	2.86	.349+17	.323-16	.919-16	.306-06
24.00	1.00	.06	.185+14	.324-15	.648-15	.216-05
24.00	2.00	.12	.740+14	.162-15	.344-15	.115-05
24.00	4.00	.24	.296+15	.810-16	.177-15	.591-06
24.00	10.00	.61	.185+16	.323-16	.759-16	.253-06
24.00	20.00	1.22	.744+16	.161-16	.371-16	.124-06
24.00	40.00	2.47	.301+17	.787-17	.182-16	.606-07

HALF LIFE .284+03 DAYS CE 144
RELEASE RATE .770-04 CURIES PER YEAR
NATURAL CONCENTRATION OF CARRIER IN SEAWATER .300-09 GRAMS PER CC
MAXIMUM PERMISSIBLE .190-06 .230+02

CURRENT VELOCITY NM/DAY	PLUME LENGTH NM	HALF WIDTH NM	VOLUME IN PLUME CC	CONCENTRATION ISO- UCI/CC	CONCENTRATION AVE. UCI/CC	AVE. SPEC. ACTIVITY UCI/GM
.50	1.00	.06	.185+14	.800-14	.160-13	.535-04
.50	2.00	.12	.743+14	.398-14	.850-14	.283-04
.50	4.00	.24	.298+15	.197-14	.435-14	.145-04
.50	10.00	.62	.189+16	.766-15	.184-14	.613-05
.50	20.00	1.26	.768+16	.365-15	.878-15	.293-05
.50	40.00	2.61	.318+17	.165-15	.413-15	.138-05
4.00	1.00	.06	.185+14	.100-14	.201-14	.670-05
4.00	2.00	.12	.740+14	.502-15	.107-14	.356-05
4.00	4.00	.24	.296+15	.251-15	.549-15	.183-05
4.00	10.00	.61	.185+16	.999-16	.235-15	.783-06
4.00	20.00	1.22	.744+16	.496-16	.115-15	.382-06
4.00	40.00	2.45	.299+17	.245-16	.564-16	.188-06
24.00	1.00	.06	.185+14	.167-15	.335-15	.112-05
24.00	2.00	.12	.740+14	.837-16	.178-15	.593-06
24.00	4.00	.24	.296+15	.419-16	.916-16	.305-06
24.00	10.00	.61	.185+16	.167-16	.393-16	.131-06
24.00	20.00	1.21	.741+16	.836-17	.192-16	.641-07
24.00	40.00	2.43	.296+17	.417-17	.950-17	.317-07

HALF LIFE .249+00 DAYS PR 145
RELEASE RATE .220-04 CURIES PER YEAR
NATURAL CONCENTRATION OF CARRIER IN SEAWATER .300-09 GRAMS PER CC
MAXIMUM PERMISSIBLE .000 .000

.50	1.00	.14	.429+14	.878-17	.284-15	.947-06
.50	2.00	.38	.231+15	.168-19	.563-16	.188-06
.50	4.00	1.04	.127+16	.123-24	.102-16	.341-07
.50	10.00	4.06	.124+17	.000	.105-17	.351-08
.50	20.00	11.42	.697+17	.000	.187-18	.623-09
.50	40.00	32.21	.393+18	.000	.332-19	.111-09
4.00	1.00	.08	.230+14	.143-15	.905-15	.135-05
4.00	2.00	.18	.107+15	.357-16	.157-15	.524-06
4.00	4.00	.43	.529+15	.444-17	.479-16	.160-06
4.00	10.00	1.54	.471+16	.273-19	.736-17	.245-07
4.00	20.00	4.19	.256+17	.130-22	.137-17	.455-08
4.00	40.00	11.61	.142+18	.587-29	.247-18	.822-09
24.00	1.00	.06	.193+14	.426-16	.903-16	.301-06
24.00	2.00	.13	.805+14	.190-16	.451-16	.150-06
24.00	4.00	.28	.346+15	.752-17	.207-16	.689-07
24.00	10.00	.84	.256+16	.150-17	.669-17	.223-07
24.00	20.00	2.04	.124+17	.235-18	.207-17	.689-08
24.00	40.00	5.23	.638+17	.116-19	.602-18	.167-08

Down-current Distribution for NORMAL OPERATION, Continuous Release

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 CURRENT   PLUME     HALF      VOLUME       CONCENTRATION  AVE. SPEC.
VELOCITY  LENGTH    WIDTH    IN PLUME        150-     AVE.   ACTIVITY
  NM/DAY      NM       NM        CC        UCI/CC   UCI/CC     UCI/GM

HALF LIFE    .111+02 DAYS               ND 147
RELEASE RATE    .510-04 CURIES PER YEAR
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .300-09 GRAMS PER CC
MAXIMUM PERMISSIBLE                                 .110-06       .190+04

     .50     1.00       .06      .194+14    .470-14 .100-13     .333-04
     .50     2.00       .13      .810+14    .207-14 .497-14     .166-04
     .50     4.00       .29      .350+15    .806-15 .226-14     .752-05
     .50    10.00       .85      .261+16    .152-15 .718-15     .239-05
     .50    20.00      2.09      .128+17    .217-16 .216-15     .719-06
     .50    40.00      5.40      .658+17    .886-18 .509-16     .170-06
    4.00     1.00       .06      .186+14    .655-15 .132-14     .440-05
    4.00     2.00       .12      .749+14    .323-15 .696-15     .232-05
    4.00     4.00       .25      .303+15    .156-15 .352-15     .117-05
    4.00    10.00       .64      .196+16    .569-16 .145-15     .482-06
    4.00    20.00      1.35      .826+16    .243-16 .653-16     .218-06
    4.00    40.00      2.96      .362+17    .889-17 .277-16     .924-07
   24.00     1.00       .06      .185+14    .111-15 .222-15     .739-06
   24.00     2.00       .12      .741+14    .552-16 .118-15     .392-06
   24.00     4.00       .24      .297+15    .274-16 .603-16     .201-06
   24.00    10.00       .61      .187+16    .108-16 .257-16     .856-07
   24.00    20.00      1.24      .755+16    .526-17 .124-16     .413-07
   24.00    40.00      2.52      .308+17    .250-17 .597-17     .199-07

HALF LIFE    .629+02 DAYS               PM 147
RELEASE RATE    .110-04 CURIES PER YEAR
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .300-09 GRAMS PER CC
MAXIMUM PERMISSIBLE                                 .380-06       .160+03
DAUGHTER OF PREVIOUS RADIONUCLIDE, DECAY FRACTION =  1.0000

     .50     1.00       .06      .180+14    .123-14 .238-14     .795-05
     .50     2.00       .12      .708+14    .651-15 .131-14     .436-05
     .50     4.00       .23      .279+15    .351-15 .706-15     .235-05
     .50    10.00       .59      .180+16    .151-15 .321-15     .107-05
     .50    20.00      1.31      .801+16    .689-16 .157-15     .525-06
     .50    40.00      3.09      .378+17    .235-16 .698-16     .233-06
    4.00     1.00       .06      .184+14    .145-15 .289-15     .962-06
    4.00     2.00       .12      .734+14    .732-16 .154-15     .514-06
    4.00     4.00       .24      .292+15    .373-16 .801-16     .267-06
    4.00    10.00       .59      .179+16    .156-16 .352-16     .117-06
    4.00    20.00      1.15      .704+16    .832-17 .179-16     .596-07
    4.00    40.00      2.28      .279+17    .450-17 .931-17     .310-07
   24.00     1.00       .06      .185+14    .240-16 .479-16     .160-06
   24.00     2.00       .12      .739+14    .120-16 .255-16     .849-07
   24.00     4.00       .24      .295+15    .602-17 .131-16     .438-07
   24.00    10.00       .60      .184+16    .243-17 .566-17     .189-07
   24.00    20.00      1.20      .731+16    .123-17 .279-17     .932-08
   24.00    40.00      2.37      .289+17    .635-18 .140-17     .468-08
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 CURRENT   PLUME     HALF      VOLUME       CONCENTRATION  AVE. SPEC.
VELOCITY  LENGTH    WIDTH    IN PLUME        150-     AVE.   ACTIVITY
  NM/DAY      NM       NM        CC        UCI/CC   UCI/CC     UCI/GM

HALF LIFE    .221+01 DAYS               PM 149
RELEASE RATE    .193-04 CURIES PER YEAR
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .300-09 GRAMS PER CC
MAXIMUM PERMISSIBLE                                 .760-07       .950+04

     .50     1.00       .07      .226+14    .108-14 .295-14     .982-05
     .50     2.00       .17      .104+15    .287-15 .117-14     .391-05
     .50     4.00       .42      .511+15    .410-16 .370-15     .123-05
     .50    10.00      1.48      .451+16    .381-18 .603-16     .201-06
     .50    20.00      4.00      .244+17    .360-21 .113-16     .376-07
     .50    40.00     11.05      .135+18    .642-27 .204-17     .681-08
    4.00     1.00       .06      .191+14    .233-15 .484-15     .161-05
    4.00     2.00       .13      .784+14    .108-15 .247-15     .822-06
    4.00     4.00       .27      .331+15    .460-16 .117-15     .390-06
    4.00    10.00       .77      .235+16    .115-16 .412-16     .137-06
    4.00    20.00      1.81      .111+17    .263-17 .143-16     .477-07
    4.00    40.00      4.52      .551+17    .274-18 .403-17     .134-07
   24.00     1.00       .06      .186+14    .414-16 .834-16     .278-06
   24.00     2.00       .12      .748+14    .204-16 .440-16     .147-06
   24.00     4.00       .25      .302+15    .996-17 .223-16     .744-07
   24.00    10.00       .64      .194+16    .368-17 .923-17     .308-07
   24.00    20.00      1.33      .813+16    .162-17 .422-17     .141-07
   24.00    40.00      2.88      .352+17    .622-18 .184-17     .612-08

HALF LIFE    .116+01 DAYS               PM 151
RELEASE RATE    .605-05 CURIES PER YEAR
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .300-09 GRAMS PER CC
MAXIMUM PERMISSIBLE                                 .000          .000

     .50     1.00       .08      .258+14    .191-15 .695-15     .232-05
     .50     2.00       .21      .126+15    .289-16 .230-15     .767-06
     .50     4.00       .53      .646+15    .133-17 .569-16     .190-06
     .50    10.00      1.96      .597+16    .409-21 .675-17     .225-07
     .50    20.00      5.40      .329+17    .132-26 .122-17     .408-08
     .50    40.00     15.08      .184+18    .277-37 .219-18     .731-09
    4.00     1.00       .06      .196+14    .680-16 .147-15     .488-06
    4.00     2.00       .13      .822+14    .293-16 .719-16     .240-06
    4.00     4.00       .29      .359+15    .109-16 .320-16     .107-06
    4.00    10.00       .89      .273+16    .177-17 .969-17     .323-07
    4.00    20.00      2.22      .135+17    .199-18 .274-17     .913-08
    4.00    40.00      5.79      .707+17    .502-20 .607-18     .202-08
   24.00     1.00       .06      .187+14    .128-16 .260-16     .866-07
   24.00     2.00       .12      .754+14    .626-17 .136-16     .454-07
   24.00     4.00       .25      .307+15    .298-17 .683-17     .228-07
   24.00    10.00       .66      .202+16    .103-17 .274-17     .912-08
   24.00    20.00      1.43      .873+16    .400-18 .118-17     .394-08
   24.00    40.00      3.24      .395+17    .122-18 .464-18     .155-08
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Down-current Distribution for NORMAL OPERATION, Continuous Release

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  CURRENT   PLUME     HALF      VOLUME       CONCENTRATION  AVE. SPEC.
 VELOCITY  LENGTH    WIDTH    IN PLUME        ISO-     AVE.   ACTIVITY
   NM/DAY      NM       NM        CC        UCI/CC   UCI/CC     UCI/GM

HALF LIFE    .318+05 DAYS              SM 151
RELEASE RATE    .705-07 CURIES PER YEAR
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .300-09 GRAMS PER CC
MAXIMUM PERMISSIBLE                               .500-06       .160+03
DAUGHTER OF PREVIOUS RADIONUCLIDE, DECAY FRACTION =  1.0000

      .50    1.00      .06     .185+14     .738-17 .147-16     .491-07
      .50    2.00      .12     .740+14     .369-17 .783-17     .261-07
      .50    4.00      .24     .296+15     .185-17 .403-17     .134-07
      .50   10.00      .61     .185+16     .738-18 .173-17     .577-08
      .50   20.00     1.21     .740+16     .369-18 .848-18     .283-08
      .50   40.00     2.43     .296+17     .184-18 .419-18     .140-08
     4.00    1.00      .06     .185+14     .920-18 .184-17     .613-08
     4.00    2.00      .12     .740+14     .460-18 .978-18     .326-08
     4.00    4.00      .24     .296+15     .230-18 .504-18     .168-08
     4.00   10.00      .61     .185+16     .922-19 .216-18     .720-09
     4.00   20.00     1.21     .740+16     .461-19 .106-18     .353-09
     4.00   40.00     2.43     .296+17     .231-19 .524-19     .175-09
    24.00    1.00      .06     .185+14     .153-18 .307-18     .102-08
    24.00    2.00      .12     .740+14     .767-19 .163-18     .543-09
    24.00    4.00      .24     .296+15     .383-19 .839-19     .280-09
    24.00   10.00      .61     .185+16     .153-19 .360-19     .120-09
    24.00   20.00     1.21     .740+16     .768-20 .176-19     .588-10
    24.00   40.00     2.42     .296+17     .384-20 .873-20     .291-10

HALF LIFE    .195+01 DAYS              SM 153
RELEASE RATE    .364-05 CURIES PER YEAR
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .300-09 GRAMS PER CC
MAXIMUM PERMISSIBLE                               .150-06       .160+05

      .50    1.00      .08     .231+14     .187-15 .533-15     .178-05
      .50    2.00      .18     .109+15     .459-16 .206-15     .685-06
      .50    4.00      .44     .533+15     .553-17 .621-16     .207-06
      .50   10.00     1.56     .475+16     .311-19 .943-17     .314-07
      .50   20.00     4.24     .258+17     .127-22 .175-17     .582-08
      .50   40.00    11.73     .143+18     .427-29 .315-18     .105-08
     4.00    1.00      .06     .191+14     .435-16 .909-16     .303-06
     4.00    2.00      .13     .790+14     .199-16 .460-16     .153-06
     4.00    4.00      .27     .335+15     .832-17 .216-16     .721-07
     4.00   10.00      .79     .241+16     .195-17 .743-17     .248-07
     4.00   20.00     1.88     .115+17     .402-18 .249-17     .831-08
     4.00   40.00     4.73     .577+17     .340-19 .670-18     .223-08
    24.00    1.00      .06     .186+14     .780-17 .157-16     .524-07
    24.00    2.00      .12     .749+14     .384-17 .828-17     .276-07
    24.00    4.00      .25     .303+15     .187-17 .420-17     .140-07
    24.00   10.00      .64     .195+16     .683-18 .173-17     .576-08
    24.00   20.00     1.35     .822+16     .294-18 .783-18     .261-08
    24.00   40.00     2.94     .358+17     .109-18 .335-18     .112-08
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  CURRENT   PLUME     HALF      VOLUME       CONCENTRATION  AVE. SPEC.
 VELOCITY  LENGTH    WIDTH    IN PLUME        ISO-     AVE.   ACTIVITY
   NM/DAY      NM       NM        CC        UCI/CC   UCI/CC     UCI/GM

HALF LIFE    .661+03 DAYS              EU 155
RELEASE RATE    .114-06 CURIES PER YEAR
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .300-09 GRAMS PER CC
MAXIMUM PERMISSIBLE                               .380-06       .270+03

      .50    1.00      .06     .185+14     .119-16 .238-16     .793-07
      .50    2.00      .12     .741+14     .593-17 .126-16     .421-07
      .50    4.00      .24     .297+15     .295-17 .648-17     .216-07
      .50   10.00      .61     .187+16     .117-17 .276-17     .921-08
      .50   20.00     1.23     .752+16     .571-18 .134-17     .446-08
      .50   40.00     2.50     .306+17     .274-18 .647-18     .216-08
     4.00    1.00      .06     .185+14     .149-17 .298-17     .992-08
     4.00    2.00      .12     .740+14     .743-18 .158-17     .527-08
     4.00    4.00      .24     .296+15     .372-18 .813-18     .271-08
     4.00   10.00      .61     .185+16     .148-18 .348-18     .116-08
     4.00   20.00     1.22     .741+16     .740-19 .170-18     .568-09
     4.00   40.00     2.44     .297+17     .368-19 .841-19     .280-09
    24.00    1.00      .06     .185+14     .248-18 .496-18     .165-08
    24.00    2.00      .12     .740+14     .124-18 .263-18     .878-09
    24.00    4.00      .24     .296+15     .620-19 .136-18     .452-09
    24.00   10.00      .61     .185+16     .248-19 .581-19     .194-09
    24.00   20.00     1.21     .740+16     .124-19 .285-19     .949-10
    24.00   40.00     2.43     .296+17     .619-20 .141-19     .469-10

HALF LIFE    .154+02 DAYS              EU 156
RELEASE RATE    .322-06 CURIES PER YEAR
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .300-09 GRAMS PER CC
MAXIMUM PERMISSIBLE                               .000          .000

      .50    1.00      .06     .191+14     .307-16 .643-16     .214-06
      .50    2.00      .13     .791+14     .140-16 .325-16     .108-06
      .50    4.00      .27     .335+15     .586-17 .153-16     .509-07
      .50   10.00      .79     .242+16     .137-17 .523-17     .174-07
      .50   20.00     1.89     .115+17     .278-18 .175-17     .583-08
      .50   40.00     4.75     .580+17     .230-19 .468-18     .156-08
     4.00    1.00      .06     .186+14     .416-17 .836-17     .279-07
     4.00    2.00      .17     .746+14     .205-17 .441-17     .147-07
     4.00    4.00      .25     .301+15     .100-17 .224-17     .748-08
     4.00   10.00      .63     .193+16     .375-18 .932-18     .311-08
     4.00   20.00     1.32     .803+16     .168-18 .430-18     .143-08
     4.00   40.00     2.82     .344+17     .670-19 .190-18     .635-09
    24.00    1.00      .06     .185+14     .699-18 .140-17     .466-08
    24.00    2.00      .12     .741+14     .349-18 .743-18     .248-08
    24.00    4.00      .24     .297+15     .174-18 .381-18     .127-08
    24.00   10.00      .61     .186+16     .687-19 .163-18     .542-09
    24.00   20.00     1.23     .751+16     .337-19 .789-19     .263-09
    24.00   40.00     2.50     .305+17     .162-19 .383-19     .128-09
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Down-current Distribution for NORMAL OPERATION, Continuous Release

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  CURRENT   PLUME    HALF     VOLUME       CONCENTRATION  AVE. SPEC.
 VELOCITY  LENGTH    WIDTH   IN PLUME        ISO-    AVE.   ACTIVITY
  NM/DAY      NM       NM       CC          UCI/CC  UCI/CC     UCI/GM

HALF LIFE   .629+00 DAYS                EU 157
RELEASE RATE   .700-07 CURIES PER YEAR
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .300-09 GRAMS PER CC
MAXIMUM PERMISSIBLE                               .000          .000

      .50     1.00      .10    .306+14     .807-18 .486-17     .162-07
      .50     2.00      .26    .156+15     .445-19 .129-17     .431-08
      .50     4.00      .68    .834+15     .272-21 .261-18     .869-09
      .50    10.00     2.60    .792+16     .197-27 .275-19     .918-10
      .50    20.00     7.25    .442+17     .265-37 .494-20     .165-10
      .50    40.00    20.35    .248+18     .000    .879-21     .293-11
     4.00     1.00      .07    .204+14     .694-18 .159-17     .531-08
     4.00     2.00      .15    .886+14     .263-18 .735-18     .245-08
     4.00     4.00      .33    .404+15     .759-19 .293-18     .978-09
     4.00    10.00     1.08    .329+16     .581-20 .719-19     .240-09
     4.00    20.00     2.80    .171+17     .185-21 .163-19     .542-10
     4.00    40.00     7.55    .921+17     .375-24 .310-20     .103-10
    24.00     1.00      .06    .188+14     .145-18 .298-18     .992-09
    24.00     2.00      .13    .766+14     .694-19 .154-18     .514-09
    24.00     4.00      .26    .317+15     .317-19 .756-19     .252-09
    24.00    10.00      .71    .216+16     .962-20 .287-19     .957-10
    24.00    20.00     1.59    .971+16     .304-20 .113-19     .377-10
    24.00    40.00     3.79    .463+17     .607-21 .381-20     .127-10

HALF LIFE   .750+00 DAYS                GD 159
RELEASE RATE   .124-07 CURIES PER YEAR
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .300-09 GRAMS PER CC
MAXIMUM PERMISSIBLE                               .150-06       .240+05

      .50     1.00      .10    .290+14     .204-18 .103-17     .343-08
      .50     2.00      .24    .146+15     .161-19 .292-18     .973-09
      .50     4.00      .63    .773+15     .199-21 .618-19     .206-09
      .50    10.00     2.39    .729+16     .122-26 .664-20     .221-10
      .50    20.00     6.65    .406+17     .575-35 .119-20     .398-11
      .50    40.00    18.67    .228+18     .000    .213-21     .709-12
     4.00     1.00      .07    .201+14     .128-18 .288-18     .961-09
     4.00     2.00      .14    .864+14     .510-19 .136-18     .453-09
     4.00     4.00      .32    .389+15     .161-19 .563-19     .188-09
     4.00    10.00     1.02    .311+16     .161-20 .148-19     .492-10
     4.00    2C.00     2.61    .159+17     .797-22 .356-20     .119-10
     4.00    40.00     6.98    .851+17     .393-24 .698-21     .233-11
    24.00     1.00      .06    .188+14     .260-19 .529-19     .176-09
    24.00     2.00      .12    .762+14     .125-19 .275-19     .917-10
    24.00     4.00      .26    .313+15     .578-20 .136-19     .453-10
    24.00    10.00      .69    .211+16     .184-20 .526-20     .175-10
    24.00    20.00     1.54    .938+16     .624-21 .214-20     .713-11
    24.00    40.00     3.61    .440+17     .145-21 .758-21     .253-11
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Down-current Distribution for LOSS-OF-COOLANT Accident, Batch Release

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RADIONUCLIDE    H 3
HALF LIFE    .447+04 DAYS
TOTAL RELEASE  .293-02 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .108+00 GRAMS PER CC
MAXIMUM PERMISSIBLE                                   .470-01     .140-02

 CURRENT     DOWN  RADIUS     TIME     VOLUME   CONCENTRATION AVE.SPEC.
VELOCITY  CURRENT                                  ISO-    AVE.  ACTIVITY
  NM/DAY       NM      NM     DAYS         CC   UCI/CC  UCI/CC    UCI/GM
     .50     1.00     .05     2.00   .164+13  .197-09 .209-09   .194-08
     .50     1.00     .10     2.00   .657+13  .135-09 .175-09   .162-08
     .50     1.00     .20     2.00   .263+14  .302-10 .962-10   .891-09
     .50     8.00     .40    16.00   .105+15  .307-11 .326-11   .302-10
     .50     8.00     .80    16.00   .420+15  .211-11 .273-11   .253-10
     .50     8.00    1.60    16.00   .168+16  .470-12 .150-11   .139-10
     .50    40.00    2.00    80.00   .263+16  .121-12 .129-12   .120-11
     .50    40.00    4.00    80.00   .105+17  .835-13 .108-12   .100-11
     .50    40.00    8.00    80.00   .420+17  .186-13 .594-13   .550-12
    4.00     1.00     .05      .25   .164+13  .197-09 .209-09   .194-08
    4.00     1.00     .10      .25   .657+13  .135-09 .175-09   .162-08
    4.00     1.00     .20      .25   .263+14  .302-10 .963-10   .891-09
    4.00     8.00     .40     2.00   .105+15  .307-11 .327-11   .303-10
    4.00     8.00     .80     2.00   .420+15  .211-11 .274-11   .253-10
    4.00     8.00    1.60     2.00   .168+16  .471-12 .150-11   .139-10
    4.00    40.00    2.00    10.00   .263+16  .123-12 .131-12   .121-11
    4.00    40.00    4.00    10.00   .105+17  .844-13 .109-12   .101-11
    4.00    40.00    8.00    10.00   .420+17  .188-13 .601-13   .556-12
   24.00     1.00     .05      .04   .164+13  .197-09 .209-09   .194-08
   24.00     1.00     .10      .04   .657+13  .135-09 .175-09   .162-08
   24.00     1.00     .20      .04   .263+14  .302-10 .963-10   .891-09
   24.00     8.00     .40      .33   .105+15  .307-11 .327-11   .303-10
   24.00     8.00     .80      .33   .420+15  .211-11 .274-11   .254-10
   24.00     8.00    1.60      .33   .168+16  .471-12 .150-11   .139-10
   24.00    40.00    2.00     1.67   .263+16  .123-12 .131-12   .121-11
   24.00    40.00    4.00     1.67   .105+17  .845-13 .109-12   .101-11
   24.00    40.00    8.00     1.67   .420+17  .189-13 .602-13   .557-12
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RADIONUCLIDE   KR 83M
HALF LIFE   .775-01 DAYS
TOTAL RELEASE  .163+03 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .300-09 GRAMS PER CC
MAXIMUM PERMISSIBLE                                 .300          .000

 CURRENT     DOWN  RADIUS     TIME     VOLUME   CONCENTRATION AVE.SPEC.
VELOCITY  CURRENT                                  ISO-    AVE.  ACTIVITY
  NM/DAY       NM      NM     DAYS         CC   UCI/CC  UCI/CC    UCI/GM
     .50     1.00     .05     2.00   .164+13  .187-12 .199-12   .664-03
     .50     1.00     .10     2.00   .657+13  .129-12 .167-12   .556-03
     .50     1.00     .20     2.00   .263+14  .287-13 .916-13   .305-03
     .50     8.00     .40    16.00   .105+15  .000    .000      .000
     .50     8.00     .80    16.00   .420+15  .000    .000      .000
     .50     8.00    1.60    16.00   .168+16  .000    .000      .000
     .50    40.00    2.00    80.00   .263+16  .000    .000      .000
     .50    40.00    4.00    80.00   .105+17  .000    .000      .000
     .50    40.00    8.00    80.00   .420+17  .000    .000      .000
    4.00     1.00     .05      .25   .164+13  .117-05 .125-05   .415+04
    4.00     1.00     .10      .25   .657+13  .805-06 .104-05   .348+04
    4.00     1.00     .20      .25   .263+14  .190-06 .573-06   .191+04
    4.00     8.00     .40     2.00   .105+15  .293-14 .311-14   .104-04
    4.00     8.00     .80     2.00   .420+15  .201-14 .261-14   .869-05
    4.00     8.00    1.60     2.00   .168+16  .449-15 .143-14   .477-05
    4.00    40.00    2.00    10.00   .263+16  .000    .000      .000
    4.00    40.00    4.00    10.00   .105+17  .000    .000      .000
    4.00    40.00    8.00    10.00   .420+17  .000    .000      .000
   24.00     1.00     .05      .04   .164+13  .754-05 .802-05   .267+05
   24.00     1.00     .10      .04   .657+13  .518-05 .672-05   .224+05
   24.00     1.00     .20      .04   .263+14  .116-05 .369-05   .123+05
   24.00     8.00     .40      .33   .105+15  .868-08 .924-08   .308+02
   24.00     8.00     .80      .33   .420+15  .597-08 .773-08   .258+02
   24.00     8.00    1.60      .33   .168+16  .133-08 .425-08   .142+02
   24.00    40.00    2.00     1.67   .263+16  .231-14 .245-14   .818-05
   24.00    40.00    4.00     1.67   .105+17  .158-14 .205-14   .684-05
   24.00    40.00    8.00     1.67   .420+17  .354-15 .113-14   .376-05
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Down-current Distribution for LOSS-OF-COOLANT Accident, Batch Release

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RADIONUCLIDE   BR 84
HALF LIFE   .221-01 DAYS
TOTAL RELEASE  .290+01 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .650-04 GRAMS PER CC
MAXIMUM PERMISSIBLE                                 .000         .000

 CURRENT     DOWN  RADIUS     TIME    VOLUME   CONCENTRATION AVE.SPEC.
VELOCITY CURRENT                                  ISO-    AVE.  ACTIVITY
 NM/DAY       NM      NM     DAYS        CC    UCI/CC  UCI/CC    UCI/GM
     .50    1.00     .05     2.00   .164+13  .113-33 .120-33   .185-29
     .50    1.00     .10     2.00   .657+13  .776-34 .101-33   .155-29
     .50    1.00     .20     2.00   .263+14  .173-34 .552-34   .850-30
     .50    8.00     .40    16.00   .105+15  .000    .000      .000
     .50    8.00     .80    16.00   .420+15  .000    .000      .000
     .50    8.00    1.60    16.00   .168+16  .000    .000      .000
     .50   40.00    2.00    80.00   .263+16  .000    .000      .000
     .50   40.00    4.00    80.00   .105+17  .000    .000      .000
     .50   40.00    8.00    80.00   .420+17  .000    .000      .000
    4.00    1.00     .05      .25   .164+13  .767-10 .816-10   .126-05
    4.00    1.00     .10      .25   .657+13  .527-10 .683-10   .105-05
    4.00    1.00     .20      .25   .263+14  .118-10 .375-10   .577-06
    4.00    8.00     .40     2.00   .105+15  .174-35 .188-35   .289-31
    4.00    8.00     .80     2.00   .420+15  .121-35 .157-35   .242-31
    4.00    8.00    1.60     2.00   .169+16  .271-36 .863-36   .133-31
    4.00   40.00    2.00    10.00   .263+16  .000    .000      .000
    4.00   40.00    4.00    10.00   .105+17  .000    .000      .000
    4.00   40.00    8.00    10.00   .420+17  .000    .000      .000
   24.00    1.00     .05      .04   .164+13  .527-07 .561-07   .863-03
   24.00    1.00     .10      .04   .657+13  .362-07 .470-07   .722-03
   24.00    1.00     .20      .04   .263+14  .109-08 .258-07   .397-03
   24.00    8.00     .40      .33   .105+15  .479-13 .935-13   .144-08
   24.00    8.00     .80      .33   .420+15  .604-13 .783-13   .120-08
   24.00    8.00    1.60      .33   .168+16  .135-13 .430-13   .661-09
   24.00   40.00    2.00     1.67   .263+16  .244-32 .260-32   .400-28
   24.00   40.00    4.00     1.67   .105+17  .168-32 .218-32   .335-28
   24.00   40.00    8.00     1.67   .420+17  .375-33 .120-32   .184-28
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RADIONUCLIDE   KR 85M
HALF LIFE   .183+00 DAYS
TOTAL RELEASE  .409+03 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .300-09 GRAMS PER CC
MAXIMUM PERMISSIBLE                                 .000         .000

 CURRENT     DOWN  RADIUS     TIME    VOLUME   CONCENTRATION AVE.SPEC.
VELOCITY CURRENT                                  ISO-    AVE.  ACTIVITY
 NM/DAY       NM      NM     DAYS        CC    UCI/CC  UCI/CC    UCI/GM
     .50    1.00     .05     2.00   .164+13  .141-07 .150-07   .500+02
     .50    1.00     .10     2.00   .657+13  .970-08 .126-07   .419+02
     .50    1.00     .20     2.00   .263+14  .216-08 .690-08   .230+02
     .50    8.00     .40    16.00   .105+15  .208-32 .222-32   .739-23
     .50    8.00     .80    16.00   .420+15  .143-32 .185-32   .618-23
     .50    8.00    1.60    16.00   .168+16  .319-33 .102-32   .340-23
     .50   40.00    2.00    80.00   .263+16  .000    .000      .000
     .50   40.00    4.00    80.00   .105+17  .000    .000      .000
     .50   40.00    8.00    80.00   .420+17  .000    .000      .000
    4.00    1.00     .05      .25   .164+13  .107-04 .113-04   .378+05
    4.00    1.00     .10      .25   .657+13  .732-05 .949-05   .316+05
    4.00    1.00     .20      .25   .263+14  .163-05 .521-05   .174+05
    4.00    8.00     .40     2.00   .105+15  .220-09 .235-09   .782+00
    4.00    8.00     .80     2.00   .420+15  .152-09 .196-09   .655+00
    4.00    8.00    1.60     2.00   .168+16  .338-10 .108-09   .360+00
    4.00   40.00    2.00    10.00   .263+16  .614-24 .654-24   .218-14
    4.00   40.00    4.00    10.00   .105+17  .422-24 .547-24   .182-14
    4.00   40.00    8.00    10.00   .420+17  .942-25 .301-24   .100-14
   24.00    1.00     .05      .04   .164+13  .235-04 .250-04   .832+05
   24.00    1.00     .10      .04   .657+13  .161-04 .209-04   .696+05
   24.00    1.00     .20      .04   .263+14  .360-05 .115-04   .383+05
   24.00    8.00     .40      .33   .105+15  .121-06 .129-06   .431+03
   24.00    8.00     .80      .33   .420+15  .835-07 .108-06   .361+03
   24.00    8.00    1.60      .33   .168+16  .186-07 .594-07   .198+03
   24.00   40.00    2.00     1.67   .263+16  .312-10 .332-10   .111+00
   24.00   40.00    4.00     1.67   .105+17  .214-10 .278-10   .925-01
   24.00   40.00    8.00     1.67   .420+17  .478-11 .152-10   .508-01
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Down-current Distribution for LOSS-OF-COOLANT Accident, Batch Release

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RADIONUCLIDE   KR 85
HALF LIFE   .393+04 DAYS
TOTAL RELEASE  .112+02 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .300-09 GRAMS PER CC
MAXIMUM PERMISSIBLE                                    .000        .000
DAUGHTER OF PREVIOUS RADIONUCLIDE, DECAY FRACTION =    .2300

 CURRENT    DOWN   RADIUS     TIME    VOLUME     CONCENTRATION AVE.SPEC.
VELOCITY CURRENT                                  ISO-    AVE.  ACTIVITY
  NM/DAY      NM       NM     DAYS        CC    UCI/CC  UCI/CC    UCI/GM
     .50    1.00      .05     2.00  .164+13   .752-06 .800-06   .267+04
     .50    1.00      .10     2.00  .657+13   .517-06 .670-06   .223+04
     .50    1.00      .20     2.00  .263+14   .115-06 .368-06   .123+04
     .50    8.00      .40    16.00  .105+15   .117-07 .125-07   .416+02
     .50    8.00      .80    16.00  .420+15   .806-08 .104-07   .348+02
     .50    8.00     1.60    16.00  .168+16   .180-08 .574-08   .191+02
     .50   40.00     2.00    80.00  .263+16   .464-09 .493-09   .164+01
     .50   40.00     4.00    80.00  .105+17   .319-09 .413-09   .138+01
     .50   40.00     8.00    80.00  .420+17   .711-10 .227-09   .756+00
    4.00    1.00      .05      .25  .164+13   .752-06 .800-06   .267+04
    4.00    1.00      .10      .25  .657+13   .517-06 .670-06   .223+04
    4.00    1.00      .20      .25  .263+14   .115-06 .368-06   .123+04
    4.00    8.00      .40     2.00  .105+15   .118-07 .125-07   .417+02
    4.00    8.00      .80     2.00  .420+15   .808-08 .105-07   .349+02
    4.00    8.00     1.60     2.00  .168+16   .180-08 .575-08   .192+02
    4.00   40.00     2.00    10.00  .263+16   .469-09 .499-09   .166+01
    4.00   40.00     4.00    10.00  .105+17   .323-09 .418-09   .139+01
    4.00   40.00     8.00    10.00  .420+17   .720-10 .230-09   .766+00
   24.00    1.00      .05      .04  .164+13   .752-06 .800-06   .267+04
   24.00    1.00      .10      .04  .657+13   .517-06 .670-06   .223+04
   24.00    1.00      .20      .04  .263+14   .115-06 .368-06   .123+04
   24.00    8.00      .40      .33  .105+15   .118-07 .125-07   .417+02
   24.00    8.00      .80      .33  .420+15   .808-08 .105-07   .349+02
   24.00    8.00     1.60      .33  .168+16   .180-08 .575-08   .192+02
   24.00   40.00     2.00     1.67  .263+16   .470-09 .500-09   .167+01
   24.00   40.00     4.00     1.67  .105+17   .323-09 .419-09   .140+01
   24.00   40.00     8.00     1.67  .420+17   .721-10 .230-09   .767+00
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RADIONUCLIDE   KR 87
HALF LIFE   .528-01 DAYS
TOTAL RELEASE  .786+03 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .300-09 GRAMS PER CC
MAXIMUM PERMISSIBLE                                    .000        .000

 CURRENT    DOWN   RADIUS     TIME    VOLUME     CONCENTRATION AVE.SPEC.
VELOCITY CURRENT                                  ISO-    AVE.  ACTIVITY
  NM/DAY      NM       NM     DAYS        CC    UCI/CC  UCI/CC    UCI/GM
     .50    1.00      .05     2.00  .164+13   .210-15 .223-15   .745-06
     .50    1.00      .10     2.00  .657+13   .144-15 .187-15   .623-06
     .50    1.00      .20     2.00  .263+14   .322-16 .103-15   .343-06
     .50    8.00      .40    16.00  .105+15   .000    .000      .000
     .50    8.00      .80    16.00  .420+15   .000    .000      .000
     .50    8.00     1.60    16.00  .168+16   .000    .000      .000
     .50   40.00     2.00    80.00  .263+16   .000    .000      .000
     .50   40.00     4.00    80.00  .105+17   .000    .000      .000
     .50   40.00     8.00    80.00  .420+17   .000    .000      .000
    4.00    1.00      .05      .25  .164+13   .198-05 .211-05   .703+04
    4.00    1.00      .10      .25  .657+13   .136-05 .177-05   .589+04
    4.00    1.00      .20      .25  .263+14   .304-06 .971-06   .324+04
    4.00    8.00      .40     2.00  .105+15   .328-17 .349-17   .116-07
    4.00    8.00      .80     2.00  .420+15   .226-17 .292-17   .974-08
    4.00    8.00     1.60     2.00  .168+16   .503-18 .161-17   .535-08
    4.00   40.00     2.00    10.00  .263+16   .000    .000      .000
    4.00   40.00     4.00    10.00  .105+17   .000    .000      .000
    4.00   40.00     8.00    10.00  .420+17   .000    .000      .000
   24.00    1.00      .05      .04  .164+13   .306-04 .325-04   .108+06
   24.00    1.00      .10      .04  .657+13   .210-04 .272-04   .907+05
   24.00    1.00      .20      .04  .263+14   .469-05 .149-04   .498+05
   24.00    8.00      .40      .33  .105+15   .104-07 .110-07   .368+02
   24.00    8.00      .80      .33  .420+15   .714-08 .925-08   .308+02
   24.00    8.00     1.60      .33  .168+16   .159-08 .508-08   .169+02
   24.00   40.00     2.00     1.67  .263+16   .104-16 .111-16   .370-07
   24.00   40.00     4.00     1.67  .105+17   .717-17 .929-17   .310-07
   24.00   40.00     8.00     1.67  .420+17   .160-17 .510-17   .170-07
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Down-current Distribution for LOSS-OF-COOLANT Accident, Batch Release

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RADIONUCLIDE   KR 88
HALF LIFE   .117+00 DAYS
TOTAL RELEASE  .112+04 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .300-09 GRAMS PER CC
MAXIMUM PERMISSIBLE                                   .000        .000

 CURRENT    DOWN   RADIUS     TIME    VOLUME    CONCENTRATION AVE.SPEC.
VELOCITY CURRENT                                    150-    AVE.  ACTIVITY
  NM/DAY      NM       NM     DAYS        CC    UCI/CC  UCI/CC    UCI/GM
     .50    1.00      .05     2.00  .164+13  .539-09 .573-09   .191+01
     .50    1.00      .10     2.00  .657+13  .370-09 .480-09   .160+01
     .50    1.00      .20     2.00  .263+14  .827-10 .264-09   .879+00
     .50    8.00      .40    16.00  .105+15  .000    .000      .000
     .50    8.00      .80    16.00  .420+15  .000    .000      .000
     .50    8.00     1.60    16.00  .168+16  .000    .000      .000
     .50   40.00     2.00    80.00  .263+16  .000    .000      .000
     .50   40.00     4.00    80.00  .105+17  .000    .000      .000
     .50   40.00     8.00    80.00  .420+17  .000    .000      .000
    4.00    1.00      .05      .25  .164+13  .171-04 .182-04   .607+05
    4.00    1.00      .10      .25  .657+13  .118-04 .152-04   .508+05
    4.00    1.00      .20      .25  .263+14  .262-05 .837-05   .279+05
    4.00    8.00      .40     2.00  .105+15  .842-11 .896-11   .299-01
    4.00    8.00      .80     2.00  .420+15  .579-11 .750-11   .250-01
    4.00    8.00     1.60     2.00  .168+16  .129-11 .412-11   .137-01
    4.00   40.00     2.00    10.00  .263+16  .888-33 .945-33   .315-23
    4.00   40.00     4.00    10.00  .105+17  .611-33 .791-33   .264-23
    4.00   40.00     8.00    10.00  .420+17  .136-33 .435-33   .145-23
   24.00    1.00      .05      .04  .164+13  .588-04 .625-04   .208+06
   24.00    1.00      .10      .04  .657+13  .404-04 .523-04   .174+06
   24.00    1.00      .20      .04  .263+14  .901-05 .288-04   .958+05
   24.00    8.00      .40      .33  .105+15  .163-06 .174-06   .579+03
   24.00    8.00      .80      .33  .420+15  .112-06 .145-06   .484+03
   24.00    8.00     1.60      .33  .168+16  .250-07 .798-07   .266+03
   24.00   40.00     2.00     1.67  .263+16  .243-11 .258-11   .860-02
   24.00   40.00     4.00     1.67  .105+17  .167-11 .216-11   .720-02
   24.00   40.00     8.00     1.67  .420+17  .372-12 .119-11   .396-02
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RADIONUCLIDE   RB 88
HALF LIFE   .124-01 DAYS
TOTAL RELEASE  .112+02 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .120-06 GRAMS PER CC
MAXIMUM PERMISSIBLE                                  .000        .000
DAUGHTER OF PREVIOUS RADIONUCLIDE, DECAY FRACTION =  1.0000

 CURRENT    DOWN   RADIUS     TIME    VOLUME    CONCENTRATION AVE.SPEC.
VELOCITY CURRENT                                    150-    AVE.  ACTIVITY
  NM/DAY      NM       NM     DAYS        CC    UCI/CC  UCI/CC    UCI/GM
     .50    1.00      .05     2.00  .164+13  .603-09 .641-09   .534-02
     .50    1.00      .10     2.00  .657+13  .414-09 .537-09   .447-02
     .50    1.00      .20     2.00  .263+14  .925-10 .295-09   .246-02
     .50    8.00      .40    16.00  .105+15  .000    .000      .000
     .50    8.00      .80    16.00  .420+15  .000    .000      .000
     .50    8.00     1.60    16.00  .168+16  .000    .000      .000
     .50   40.00     2.00    80.00  .263+16  .000    .000      .000
     .50   40.00     4.00    80.00  .105+17  .000    .000      .000
     .50   40.00     8.00    80.00  .420+17  .000    .000      .000
    4.00    1.00      .05      .25  .164+13  .181-04 .204-04   .170+03
    4.00    1.00      .10      .25  .657+13  .132-04 .170-04   .142+03
    4.00    1.00      .20      .25  .263+14  .293-05 .936-05   .780+02
    4.00    8.00      .40     2.00  .105+15  .942-11 .100-10   .835-04
    4.00    8.00      .80     2.00  .420+15  .647-11 .839-11   .699-04
    4.00    8.00     1.60     2.00  .168+16  .144-11 .461-11   .384-04
    4.00   40.00     2.00    10.00  .263+16  .994-33 .106-32   .881-26
    4.00   40.00     4.00    10.00  .105+17  .683-33 .885-33   .737-26
    4.00   40.00     8.00    10.00  .420+17  .152-33 .486-33   .405-26
   24.00    1.00      .05      .04  .164+13  .576-04 .613-04   .511+03
   24.00    1.00      .10      .04  .657+13  .396-04 .513-04   .428+03
   24.00    1.00      .20      .04  .263+14  .883-05 .282-04   .235+03
   24.00    8.00      .40      .33  .105+15  .183-06 .194-06   .162+01
   24.00    8.00      .80      .33  .420+15  .125-06 .163-06   .135+01
   24.00    8.00     1.60      .33  .168+16  .290-07 .893-07   .744+00
   24.00   40.00     2.00     1.67  .263+16  .271-11 .289-11   .241-04
   24.00   40.00     4.00     1.67  .105+17  .187-11 .242-11   .201-04
   24.00   40.00     8.00     1.67  .420+17  .416-12 .133-11   .111-04
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Down-current Distribution for LOSS-OF-COOLANT Accident, Batch Release

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RADIONUCLIDE   RB 89
HALF LIFE   .107-01 DAYS
TOTAL RELEASE  .149+02 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .120-06 GRAMS PER CC
MAXIMUM PERMISSIBLE                                    .000        .000

 CURRENT    DOWN  RADIUS     TIME    VOLUME   CONCENTRATION AVE.SPEC.
VELOCITY CURRENT                               ISO-    AVE.  ACTIVITY
  NM/DAY      NM      NM     DAYS        CC  UCI/CC  UCI/CC    UCI/GM
     .50    1.00     .05     2.00  .164+13  .000    .000      .000
     .50    1.00     .10     2.00  .657+13  .000    .000      .000
     .50    1.00     .20     2.00  .263+14  .000    .000      .000
     .50    8.00     .40    16.00  .105+15  .000    .000      .000
     .50    8.00     .80    16.00  .420+15  .000    .000      .000
     .50    8.00    1.60    16.00  .168+16  .000    .000      .000
     .50   40.00    2.00    80.00  .263+16  .000    .000      .000
     .50   40.00    4.00    80.00  .105+17  .000    .000      .000
     .50   40.00    8.00    80.00  .420+17  .000    .000      .000
    4.00    1.00     .05      .25  .164+13  .930-13 .989-13   .824-06
    4.00    1.00     .10      .25  .657+13  .639-13 .828-13   .690-06
    4.00    1.00     .20      .25  .263+14  .143-13 .455-13   .379-06
    4.00    8.00     .40     2.00  .105+15  .000    .000      .000
    4.00    8.00     .80     2.00  .420+15  .000    .000      .000
    4.00    8.00    1.60     2.00  .168+16  .000    .000      .000
    4.00   40.00    2.00    10.00  .263+16  .000    .000      .000
    4.00   40.00    4.00    10.00  .105+17  .000    .000      .000
    4.00   40.00    8.00    10.00  .420+17  .000    .000      .000
   24.00    1.00     .05      .04  .164+13  .673-07 .716-07   .597+00
   24.00    1.00     .10      .04  .657+13  .463-07 .600-07   .500+00
   24.00    1.00     .20      .04  .263+14  .193-07 .329-07   .275+00
   24.00    8.00     .40      .33  .105+15  .658-17 .700-17   .583-10
   24.00    8.00     .80      .33  .420+15  .452-17 .586-17   .488-10
   24.00    8.00    1.60      .33  .168+16  .101-17 .322-17   .268-10
   24.00   40.00    2.00     1.67  .263+16  .000    .000      .000
   24.00   40.00    4.00     1.67  .105+17  .000    .000      .000
   24.00   40.00    8.00     1.67  .420+17  .000    .000      .000
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RADIONUCLIDE   SR 89
HALF LIFE   .527+02 DAYS
TOTAL RELEASE  .149+02 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .800-05 GRAMS PER CC
MAXIMUM PERMISSIBLE                                  .790-05     .110+04
DAUGHTER OF PREVIOUS RADIONUCLIDE, DECAY FRACTION =  1.0000

 CURRENT    DOWN  RADIUS     TIME    VOLUME   CONCENTRATION AVE.SPEC.
VELOCITY CURRENT                               ISO-    AVE.  ACTIVITY
  NM/DAY      NM      NM     DAYS        CC  UCI/CC  UCI/CC    UCI/GM
     .50    1.00     .05     2.00  .164+13  .975-06 .104-05   .130+00
     .50    1.00     .10     2.00  .657+13  .670-06 .868-06   .109+00
     .50    1.00     .20     2.00  .263+14  .150-06 .477-06   .596-01
     .50    8.00     .40    16.00  .105+15  .127-07 .135-07   .168-02
     .50    8.00     .80    16.00  .420+15  .871-09 .113-07   .141-02
     .50    8.00    1.60    16.00  .168+16  .194-09 .620-08   .775-03
     .50   40.00    2.00    80.00  .263+16  .218-09 .232-09   .290-04
     .50   40.00    4.00    80.00  .105+17  .150-09 .195-09   .243-04
     .50   40.00    8.00    80.00  .420+17  .335-10 .107-09   .134-04
    4.00    1.00     .05      .25  .164+13  .998-06 .106-05   .133+00
    4.00    1.00     .10      .25  .657+13  .686-06 .888-06   .111+00
    4.00    1.00     .20      .25  .263+14  .153-06 .488-06   .610-01
    4.00    8.00     .40     2.00  .105+15  .152-07 .162-07   .203-02
    4.00    8.00     .80     2.00  .420+15  .105-07 .136-07   .170-02
    4.00    8.00    1.60     2.00  .168+16  .234-09 .745-08   .932-03
    4.00   40.00    2.00    10.00  .263+16  .548-09 .583-09   .729-04
    4.00   40.00    4.00    10.00  .105+17  .377-09 .488-09   .611-04
    4.00   40.00    8.00    10.00  .420+17  .841-10 .268-09   .335-04
   24.00    1.00     .05      .04  .164+13  .100-05 .106-05   .133+00
   24.00    1.00     .10      .04  .657+13  .687-06 .891-06   .111+00
   24.00    1.00     .20      .04  .263+14  .153-06 .489-06   .612-01
   24.00    8.00     .40      .33  .105+15  .156-07 .166-07   .207-02
   24.00    8.00     .80      .33  .420+15  .107-07 .139-07   .173-02
   24.00    8.00    1.60      .33  .168+16  .239-08 .762-08   .952-03
   24.00   40.00    2.00     1.67  .263+16  .612-09 .651-09   .814-04
   24.00   40.00    4.00     1.67  .105+17  .421-09 .545-09   .681-04
   24.00   40.00    8.00     1.67  .420+17  .938-10 .299-09   .374-04
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Down-current Distribution for LOSS-OF-COOLANT Accident, Batch Release

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RADIONUCLIDE   SR 90
HALF LIFE   .101+05 DAYS
TOTAL RELEASE  .856+00 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .800-05 GRAMS PER CC
MAXIMUM PERMISSIBLE                                    .790-07     .920+01

 CURRENT    DOWN   RADIUS     TIME    VOLUME     CONCENTRATION AVE.SPEC.
VELOCITY CURRENT                                  ISO-    AVE.  ACTIVITY
  NM/DAY      NM       NM     DAYS          CC   UCI/CC  UCI/CC    UCI/GM
     .50    1.00      .05     2.00   .164+13  .575-07 .611-07   .764-02
     .50    1.00      .10     2.00   .657+13  .395-07 .512-07   .690-02
     .50    1.00      .20     2.00   .263+14  .881-08 .281-07   .352-02
     .50    8.00      .40    16.00   .105+15  .897-09 .954-09   .119-03
     .50    8.00      .80    16.00   .420+15  .617-09 .799-09   .999-04
     .50    8.00     1.60    16.00   .168+16  .138-09 .439-09   .549-04
     .50   40.00     2.00    80.00   .263+16  .357-10 .380-10   .475-05
     .50   40.00     4.00    80.00   .105+17  .246-10 .318-10   .398-05
     .50   40.00     8.00    80.00   .420+17  .548-11 .175-10   .219-05
    4.00    1.00      .05      .25   .164+13  .575-07 .612-07   .764-02
    4.00    1.00      .10      .25   .657+13  .395-07 .512-07   .690-02
    4.00    1.00      .20      .25   .263+14  .882-08 .281-07   .352-02
    4.00    8.00      .40     2.00   .105+15  .898-09 .955-09   .119-03
    4.00    8.00      .80     2.00   .420+15  .617-09 .800-09   .100-03
    4.00    8.00     1.60     2.00   .168+16  .138-09 .439-09   .549-04
    4.00   40.00     2.00    10.00   .263+16  .359-10 .382-10   .477-05
    4.00   40.00     4.00    10.00   .105+17  .247-10 .320-10   .400-05
    4.00   40.00     8.00    10.00   .420+17  .551-11 .176-10   .220-05
   24.00    1.00      .05      .04   .164+13  .575-07 .612-07   .764-02
   24.00    1.00      .10      .04   .657+13  .395-07 .512-07   .690-02
   24.00    1.00      .20      .04   .263+14  .882-08 .281-07   .352-02
   24.00    8.00      .40      .33   .105+15  .898-09 .956-09   .119-03
   24.00    8.00      .80      .33   .420+15  .617-09 .800-09   .100-03
   24.00    8.00     1.60      .33   .168+16  .138-09 .439-09   .549-04
   24.00   40.00     2.00     1.67   .263+16  .359-10 .382-10   .478-05
   24.00   40.00     4.00     1.67   .105+17  .247-10 .320-10   .400-05
   24.00   40.00     8.00     1.67   .420+17  .551-11 .176-10   .220-05
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RADIONUCLIDE     Y 90
HALF LIFE   .267+01 DAYS
TOTAL RELEASE  .856+00 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .100-09 GRAMS PER CC
MAXIMUM PERMISSIBLE                                   .380-06     .300+05
DAUGHTER OF PREVIOUS RADIONUCLIDE, DECAY FRACTION =  1.0000

 CURRENT    DOWN   RADIUS     TIME    VOLUME     CONCENTRATION AVE.SPEC.
VELOCITY CURRENT                                  ISO-    AVE.  ACTIVITY
  NM/DAY      NM       NM     DAYS          CC   UCI/CC  UCI/CC    UCI/GM
     .50    1.00      .05     2.00   .164+13  .575-07 .612-07   .204+03
     .50    1.00      .10     2.00   .657+13  .395-07 .512-07   .171+03
     .50    1.00      .20     2.00   .263+14  .882-08 .281-07   .937+02
     .50    8.00      .40    16.00   .105+15  .897-09 .955-09   .318+01
     .50    8.00      .80    16.00   .420+15  .617-09 .799-09   .266+01
     .50    8.00     1.60    16.00   .168+16  .138-09 .439-09   .146+01
     .50   40.00     2.00    80.00   .263+16  .357-10 .380-10   .127+00
     .50   40.00     4.00    80.00   .105+17  .246-10 .318-10   .106+00
     .50   40.00     8.00    80.00   .420+17  .548-11 .175-10   .583-01
    4.00    1.00      .05      .25   .164+13  .575-07 .612-07   .204+03
    4.00    1.00      .10      .25   .657+13  .395-07 .512-07   .171+03
    4.00    1.00      .20      .25   .263+14  .882-08 .281-07   .938+02
    4.00    8.00      .40     2.00   .105+15  .898-09 .956-09   .319+01
    4.00    8.00      .80     2.00   .420+15  .617-09 .800-09   .267+01
    4.00    8.00     1.60     2.00   .168+16  .138-09 .439-09   .146+01
    4.00   40.00     2.00    10.00   .263+16  .359-10 .382-10   .127+00
    4.00   40.00     4.00    10.00   .105+17  .247-10 .320-10   .107+00
    4.00   40.00     8.00    10.00   .420+17  .551-11 .176-10   .586-01
   24.00    1.00      .05      .04   .164+13  .575-07 .612-07   .204+03
   24.00    1.00      .10      .04   .657+13  .395-07 .512-07   .171+03
   24.00    1.00      .20      .04   .263+14  .882-08 .281-07   .938+02
   24.00    8.00      .40      .33   .105+15  .898-09 .956-09   .319+01
   24.00    8.00      .80      .33   .420+15  .617-09 .800-09   .267+01
   24.00    8.00     1.60      .33   .168+16  .138-09 .439-09   .146+01
   24.00   40.00     2.00     1.67   .263+16  .359-10 .382-10   .127+00
   24.00   40.00     4.00     1.67   .105+17  .247-10 .320-10   .107+00
   24.00   40.00     8.00     1.67   .420+17  .551-11 .176-10   .586-01
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Down-current Distribution for LOSS-OF-COOLANT Accident, Batch Release

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RADIONUCLIDE   SR 91
HALF LIFE   .403+00 DAYS
TOTAL RELEASE  .181+02 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .800-05 GRAMS PER CC
MAXIMUM PERMISSIBLE                                  .400-04    .780+05

 CURRENT    DOWN  RADIUS     TIME    VOLUME    CONCENTRATION AVE.SPEC.
VELOCITY CURRENT                                  ISO-    AVE.  ACTIVITY
  NM/DAY      NM      NM     DAYS        CC   UCI/CC  UCI/CC    UCI/GM
     .50    1.00     .05     2.00   .164+13  .390-07 .415-07   .519-02
     .50    1.00     .10     2.00   .657+13  .268-07 .347-07   .434-02
     .50    1.00     .20     2.00   .263+14  .598-08 .191-07   .239-02
     .50    8.00     .40    16.00   .105+15  .214-19 .227-19   .284-14
     .50    8.00     .80    16.00   .420+15  .147-19 .190-19   .238-14
     .50    8.00    1.60    16.00   .168+16  .328-20 .104-19   .131-14
     .50   40.00    2.00    80.00   .263+16  .000    .000      .000
     .50   40.00    4.00    80.00   .105+17  .000    .000      .000
     .50   40.00    8.00    80.00   .420+17  .000    .000      .000
    4.00    1.00     .05      .25   .164+13  .791-06 .841-06   .105+00
    4.00    1.00     .10      .25   .657+13  .544-06 .704-06   .880-01
    4.00    1.00     .20      .25   .263+14  .121-06 .387-06   .484-01
    4.00    8.00     .40     2.00   .105+15  .609-09 .648-09   .810-04
    4.00    8.00     .80     2.00   .420+15  .419-09 .543-09   .678-04
    4.00    8.00    1.60     2.00   .168+16  .935-10 .298-09   .373-04
    4.00   40.00    2.00    10.00   .263+16  .259-16 .275-16   .344-11
    4.00   40.00    4.00    10.00   .105+17  .178-16 .230-16   .288-11
    4.00   40.00    8.00    10.00   .420+17  .396-17 .126-16   .158-11
   24.00    1.00     .05      .04   .164+13  .113-05 .120-05   .150+00
   24.00    1.00     .10      .04   .657+13  .778-06 .101-05   .126+00
   24.00    1.00     .20      .04   .263+14  .174-06 .554-06   .692-01
   24.00    8.00     .40      .33   .105+15  .107-07 .114-07   .142-02
   24.00    8.00     .80      .33   .420+15  .736-08 .953-08   .119-02
   24.00    8.00    1.60      .33   .168+16  .164-08 .524-08   .655-03
   24.00   40.00    2.00     1.67   .263+16  .432-10 .460-10   .575-05
   24.00   40.00    4.00     1.67   .105+17  .297-10 .385-10   .481-05
   24.00   40.00    8.00     1.67   .420+17  .663-11 .212-10   .264-05
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RADIONUCLIDE    Y 91
HALF LIFE   .588+02 DAYS
TOTAL RELEASE  .184+02 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .300-09 GRAMS PER CC
MAXIMUM PERMISSIBLE                                  .570-06    .230+04
DAUGHTER OF PREVIOUS RADIONUCLIDE, DECAY FRACTION =  1.0000

 CURRENT    DOWN  RADIUS     TIME    VOLUME    CONCENTRATION AVE.SPEC.
VELOCITY CURRENT                                  ISO-    AVE.  ACTIVITY
  NM/DAY      NM      NM     DAYS        CC   UCI/CC  UCI/CC    UCI/GM
     .50    1.00     .05     2.00   .164+13  .121-05 .129-05   .431+04
     .50    1.00     .10     2.00   .657+13  .935-06 .108-05   .361+04
     .50    1.00     .20     2.00   .263+14  .186-06 .594-06   .198+04
     .50    8.00     .40    16.00   .105+15  .161-07 .171-07   .571+02
     .50    8.00     .80    16.00   .420+15  .111-07 .143-07   .478+02
     .50    8.00    1.60    16.00   .168+16  .247-08 .788-08   .263+02
     .50   40.00    2.00    80.00   .263+16  .303-09 .322-09   .107+01
     .50   40.00    4.00    80.00   .105+17  .208-09 .270-09   .899+00
     .50   40.00    8.00    80.00   .420+17  .464-10 .148-09   .494+00
    4.00    1.00     .05      .25   .164+13  .123-05 .131-05   .438+04
    4.00    1.00     .10      .25   .657+13  .849-06 .110-05   .367+04
    4.00    1.00     .20      .25   .263+14  .189-06 .604-06   .201+04
    4.00    8.00     .40     2.00   .105+15  .190-07 .202-07   .673+02
    4.00    8.00     .80     2.00   .420+15  .130-07 .169-07   .563+02
    4.00    8.00    1.60     2.00   .168+16  .291-08 .929-08   .310+02
    4.00   40.00    2.00    10.00   .263+16  .691-09 .735-09   .245+01
    4.00   40.00    4.00    10.00   .105+17  .475-09 .615-09   .205+01
    4.00   40.00    8.00    10.00   .420+17  .106-09 .338-09   .113+01
   24.00    1.00     .05      .04   .164+13  .124-05 .131-05   .438+04
   24.00    1.00     .10      .04   .657+13  .449-06 .110-05   .367+04
   24.00    1.00     .20      .04   .263+14  .189-06 .605-06   .202+04
   24.00    8.00     .40      .33   .105+15  .193-07 .205-07   .684+02
   24.00    8.00     .80      .33   .420+15  .133-07 .172-07   .573+02
   24.00    8.00    1.60      .33   .168+16  .296-08 .944-08   .315+02
   24.00   40.00    2.00     1.67   .263+16  .762-09 .811-09   .270+01
   24.00   40.00    4.00     1.67   .105+17  .524-09 .679-09   .226+01
   24.00   40.00    8.00     1.67   .420+17  .117-09 .373-09   .124+01
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Down-current Distribution for LOSS-OF-COOLANT Accident, Batch Release

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RADIONUCLIDE    MO 99
HALF LIFE    .278+01 DAYS
TOTAL RELEASE   .193+02 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .100-07 GRAMS PER CC
MAXIMUM PERMISSIBLE                                   .750-06      .270+04

 CURRENT     DOWN  RADIUS     TIME     VOLUME    CONCENTRATION AVE.SPEC.
VELOCITY CURRENT                                   ISO-    AVE.  ACTIVITY
  NM/DAY      NM      NM     DAYS          CC   UCI/CC  UCI/CC    UCI/GM
     .50    1.00     .05     2.00   .164+13   .787-06 .838-06   .838+02
     .50    1.00     .10     2.00   .657+13   .541-06 .701-06   .701+02
     .50    1.00     .20     2.00   .263+14   .121-06 .385-06   .385+02
     .50    8.00     .40    16.00   .105+15   .375-09 .399-09   .399-01
     .50    8.00     .80    16.00   .420+15   .258-09 .334-09   .334-01
     .50    8.00    1.60    16.00   .168+16   .575-10 .184-09   .184-01
     .50   40.00    2.00    80.00   .263+16   .177-17 .188-17   .188-09
     .50   40.00    4.00    80.00   .105+17   .122-17 .158-17   .158-09
     .50   40.00    8.00    80.00   .420+17   .271-18 .865-18   .865-10
    4.00    1.00     .05      .25   .164+13   .122-05 .130-05   .130+03
    4.00    1.00     .10      .25   .657+13   .837-06 .108-05   .108+03
    4.00    1.00     .20      .25   .263+14   .187-06 .596-06   .596+02
    4.00    8.00     .40     2.00   .105+15   .123-07 .131-07   .131+01
    4.00    8.00     .80     2.00   .420+15   .845-08 .110-07   .110+01
    4.00    8.00    1.60     2.00   .168+16   .189-08 .602-08   .602+00
    4.00   40.00    2.00    10.00   .263+16   .670-10 .712-10   .712-02
    4.00   40.00    4.00    10.00   .105+17   .460-10 .596-10   .596-02
    4.00   40.00    8.00    10.00   .420+17   .103-10 .328-10   .328-02
   24.00    1.00     .05      .04   .164+13   .128-05 .136-05   .136+03
   24.00    1.00     .10      .04   .657+13   .882-06 .114-05   .114+03
   24.00    1.00     .20      .04   .263+14   .197-06 .628-06   .628+02
   24.00    8.00     .40      .33   .105+15   .186-07 .198-07   .198+01
   24.00    8.00     .80      .33   .420+15   .128-07 .166-07   .166+01
   24.00    8.00    1.60      .33   .168+16   .286-08 .912-08   .912+00
   24.00   40.00    2.00     1.67   .263+16   .535-09 .569-09   .569-01
   24.00   40.00    4.00     1.67   .105+17   .367-09 .476-09   .476-01
   24.00   40.00    8.00     1.67   .420+17   .820-10 .262-09   .262-01
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RADIONUCLIDE    RU 103
HALF LIFE    .395+02 DAYS
TOTAL RELEASE   .938+01 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .000    GRAMS PER CC
MAXIMUM PERMISSIBLE                                   .130-05      .000

 CURRENT     DOWN  RADIUS     TIME     VOLUME    CONCENTRATION AVE.SPEC.
VELOCITY CURRENT                                   ISO-    AVE.  ACTIVITY
  NM/DAY      NM      NM     DAYS          CC   UCI/CC  UCI/CC    UCI/GM
     .50    1.00     .05     2.00   .164+13   .604-06 .647-06   .000
     .50    1.00     .10     2.00   .657+13   .414-06 .542-06   .000
     .50    1.00     .20     2.00   .263+14   .433-07 .298-06   .000
     .50    8.00     .40    16.00   .105+15   .743-08 .791-08   .000
     .50    8.00     .80    16.00   .420+15   .511-08 .662-08   .000
     .50    8.00    1.60    16.00   .168+16   .114-08 .364-08   .000
     .50   40.00    2.00    80.00   .263+16   .467-10 .103-09   .000
     .50   40.00    4.00    80.00   .105+17   .665-10 .862-10   .000
     .50   40.00    8.00    80.00   .420+17   .148-10 .473-10   .000
    4.00    1.00     .05      .25   .164+13   .627-06 .667-06   .000
    4.00    1.00     .10      .25   .657+13   .431-06 .559-06   .000
    4.00    1.00     .20      .25   .263+14   .462-07 .307-06   .000
    4.00    8.00     .40     2.00   .105+15   .450-08 .101-07   .000
    4.00    8.00     .80     2.00   .420+15   .653-08 .846-08   .000
    4.00    8.00    1.60     2.00   .168+16   .146-08 .465-08   .000
    4.00   40.00    2.00    10.00   .263+16   .330-09 .351-09   .000
    4.00   40.00    4.00    10.00   .105+17   .227-09 .294-09   .000
    4.00   40.00    8.00    10.00   .420+17   .507-10 .162-09   .000
   24.00    1.00     .05      .04   .164+13   .629-06 .670-06   .000
   24.00    1.00     .10      .04   .657+13   .433-06 .561-06   .000
   24.00    1.00     .20      .04   .263+14   .465-07 .328-06   .000
   24.00    8.00     .40      .33   .105+15   .479-08 .104-07   .000
   24.00    8.00     .80      .33   .420+15   .673-08 .971-08   .000
   24.00    8.00    1.60      .33   .168+16   .150-08 .479-08   .000
   24.00   40.00    2.00     1.67   .263+16   .382-09 .407-09   .000
   24.00   40.00    4.00     1.67   .105+17   .263-09 .341-09   .000
   24.00   40.00    8.00     1.67   .420+17   .536-10 .187-09   .000
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Down-current Distribution for LOSS-OF-COOLANT Accident, Batch Release

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RADIONUCLIDE    TE127M
HALF LIFE    .109+03 DAYS
TOTAL RELEASE   .109+00 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .000    GRAMS PER CC
MAXIMUM PERMISSIBLE
                                                      .950-06     .350+00

 CURRENT    DOWN   RADIUS     TIME    VOLUME      CONCENTRATION AVE.SPEC.
VELOCITY CURRENT                                    ISO-    AVE.  ACTIVITY
 NM/DAY      NM       NM      DAYS         CC     UCI/CC  UCI/CC    UCI/GM
    .50     1.00      .05     2.00   .164+13   .723-08 .769-08    .000
    .50     1.00      .10     2.00   .657+13   .497-08 .644-08    .000
    .50     1.00      .20     2.00   .263+14   .111-08 .354-08    .000
    .50     8.00      .40    16.00   .105+15   .103-09 .110-09    .000
    .50     8.00      .80    16.00   .420+15   .710-10 .920-10    .000
    .50     8.00     1.60    16.00   .168+16   .158-10 .505-10    .000
    .50    40.00     2.00    80.00   .263+16   .275-11 .293-11    .000
    .50    40.00     4.00    80.00   .105+17   .199-11 .245-11    .000
    .50    40.00     8.00    80.00   .420+17   .422-12 .135-11    .000
   4.00     1.00      .05      .25   .164+13   .731-08 .777-08    .000
   4.00     1.00      .10      .25   .657+13   .502-08 .651-08    .000
   4.00     1.00      .20      .25   .263+14   .112-08 .358-08    .000
   4.00     8.00      .40     2.00   .105+15   .113-09 .120-09    .000
   4.00     8.00      .80     2.00   .420+15   .776-10 .101-09    .000
   4.00     8.00     1.60     2.00   .168+16   .173-10 .553-10    .000
   4.00    40.00     2.00    10.00   .263+16   .429-11 .457-11    .000
   4.00    40.00     4.00    10.00   .105+17   .295-11 .382-11    .000
   4.00    40.00     8.00    10.00   .420+17   .658-12 .210-11    .000
  24.00     1.00      .05      .04   .164+13   .732-08 .779-08    .000
  24.00     1.00      .10      .04   .657+13   .503-08 .652-08    .000
  24.00     1.00      .20      .04   .263+14   .112-08 .358-08    .000
  24.00     8.00      .40      .33   .105+15   .114-09 .121-09    .000
  24.00     8.00      .80      .33   .420+15   .784-10 .102-09    .000
  24.00     8.00     1.60      .33   .168+16   .175-10 .558-10    .000
  24.00    40.00     2.00     1.67   .263+16   .453-11 .482-11    .000
  24.00    40.00     4.00     1.67   .105+17   .311-11 .403-11    .000
  24.00    40.00     8.00     1.67   .420+17   .694-12 .221-11    .000
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RADIONUCLIDE    TE129M
HALF LIFE    .341+02 DAYS
TOTAL RELEASE   .109+01 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .000    GRAMS PER CC
MAXIMUM PERMISSIBLE
                                                      .320-06     .180+00

 CURRENT    DOWN   RADIUS     TIME    VOLUME      CONCENTRATION AVE.SPEC.
VELOCITY CURRENT                                    ISO-    AVE.  ACTIVITY
 NM/DAY      NM       NM      DAYS         CC     UCI/CC  UCI/CC    UCI/GM
    .50     1.00      .05     2.00   .164+13   .703-07 .748-07    .000
    .50     1.00      .10     2.00   .657+13   .483-07 .626-07    .000
    .50     1.00      .20     2.00   .263+14   .108-07 .344-07    .000
    .50     8.00      .40    16.00   .105+15   .826-09 .879-09    .000
    .50     8.00      .80    16.00   .420+15   .568-09 .736-09    .000
    .50     8.00     1.60    16.00   .168+16   .127-09 .404-09    .000
    .50    40.00     2.00    80.00   .263+16   .900-11 .958-11    .000
    .50    40.00     4.00    80.00   .105+17   .619-11 .802-11    .000
    .50    40.00     8.00    80.00   .420+17   .130-11 .440-11    .000
   4.00     1.00      .05      .25   .164+13   .728-07 .775-07    .000
   4.00     1.00      .10      .25   .657+13   .501-07 .649-07    .000
   4.00     1.00      .20      .25   .263+14   .112-07 .356-07    .000
   4.00     8.00      .40     2.00   .105+15   .110-08 .117-08    .000
   4.00     8.00      .80     2.00   .420+15   .755-09 .978-09    .000
   4.00     8.00     1.60     2.00   .168+16   .168-09 .537-09    .000
   4.00    40.00     2.00    10.00   .263+16   .373-10 .397-10    .000
   4.00    40.00     4.00    10.00   .105+17   .257-10 .333-10    .000
   4.00    40.00     8.00    10.00   .420+17   .572-11 .183-10    .000
  24.00     1.00      .05      .04   .164+13   .731-07 .778-07    .000
  24.00     1.00      .10      .04   .657+13   .503-07 .651-07    .000
  24.00     1.00      .20      .04   .263+14   .112-07 .359-07    .000
  24.00     8.00      .40      .33   .105+15   .114-08 .121-08    .000
  24.00     8.00      .80      .33   .420+15   .781-09 .101-08    .000
  24.00     8.00     1.60      .33   .168+16   .174-09 .556-09    .000
  24.00    40.00     2.00     1.67   .263+16   .442-10 .470-10    .000
  24.00    40.00     4.00     1.67   .105+17   .304-10 .394-10    .000
  24.00    40.00     8.00     1.67   .420+17   .676-11 .216-10    .000
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Down-current Distribution for LOSS-OF-COOLANT Accident, Batch Release

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RADIONUCLIDE   TE 129
HALF LIFE   .477-01 DAYS
TOTAL RELEASE  .281+01 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .000    GRAMS PER CC
MAXIMUM PERMISSIBLE                                .130-09     .690+00
DAUGHTER OF PREVIOUS RADIONUCLIDE, DECAY FRACTION =    .6400

 CURRENT     DOWN  RADIUS      TIME    VOLUME     CONCENTRATION AVE.SPEC.
VELOCITY  CURRENT                                    ISO-    AVE.  ACTIVITY
  NM/DAY       NM       NM     DAYS         CC   UCI/CC  UCI/CC    UCI/GM
     .50     1.00      .05     2.00   .164+13  .450-07 .479-07    .000
     .50     1.00      .10     2.00   .657+13  .310-07 .401-07    .000
     .50     1.00      .20     2.00   .263+14  .691-08 .220-07    .000
     .50     8.00      .40    16.00   .105+15  .530-09 .563-09    .000
     .50     8.00      .80    16.00   .420+15  .364-09 .472-09    .000
     .50     8.00     1.60    16.00   .168+16  .812-10 .259-09    .000
     .50    40.00     2.00    80.00   .263+16  .577-11 .614-11    .000
     .50    40.00     4.00    80.00   .105+17  .397-11 .514-11    .000
     .50    40.00     8.00    80.00   .420+17  .885-12 .282-11    .000
    4.00     1.00      .05      .25   .164+13  .504-07 .536-07    .000
    4.00     1.00      .10      .25   .657+13  .347-07 .449-07    .000
    4.00     1.00      .20      .25   .263+14  .773-08 .247-07    .000
    4.00     8.00      .40     2.00   .105+15  .704-09 .749-09    .000
    4.00     8.00      .80     2.00   .420+15  .444-09 .627-09    .000
    4.00     8.00     1.60     2.00   .168+16  .108-09 .344-09    .000
    4.00    40.00     2.00    10.00   .263+16  .239-10 .255-10    .000
    4.00    40.00     4.00    10.00   .105+17  .164-10 .213-10    .000
    4.00    40.00     8.00    10.00   .420+17  .367-11 .117-10    .000
   24.00     1.00      .05      .04   .164+13  .124-06 .132-06    .000
   24.00     1.00      .10      .04   .657+13  .854-07 .111-06    .000
   24.00     1.00      .20      .04   .263+14  .191-07 .608-07    .000
   24.00     8.00      .40      .33   .105+15  .746-09 .793-09    .000
   24.00     8.00      .80      .33   .420+15  .512-09 .664-09    .000
   24.00     8.00     1.60      .33   .168+16  .114-09 .365-09    .000
   24.00    40.00     2.00     1.67   .263+16  .203-10 .302-10    .000
   24.00    40.00     4.00     1.67   .105+17  .195-10 .252-10    .000
   24.00    40.00     8.00     1.67   .420+17  .435-11 .139-10    .000
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RADIONUCLIDE   I 131
HALF LIFE   .805+01 DAYS
TOTAL RELEASE  .228+03 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .600-07 GRAMS PER CC
MAXIMUM PERMISSIBLE                              .320-08     .320+02

 CURRENT     DOWN  RADIUS      TIME    VOLUME     CONCENTRATION AVE.SPEC.
VELOCITY  CURRENT                                    ISO-    AVE.  ACTIVITY
  NM/DAY       NM       NM     DAYS         CC   UCI/CC  UCI/CC    UCI/GM
     .50     1.00      .05     2.00   .164+13  .129-04 .137-04  .229+03
     .50     1.00      .10     2.00   .657+13  .886-05 .115-04  .191+03
     .50     1.00      .20     2.00   .263+14  .198-05 .631-05  .105+03
     .50     8.00      .40    16.00   .105+15  .603-07 .642-07  .107+01
     .50     8.00      .80    16.00   .420+15  .415-07 .537-07  .896+00
     .50     8.00     1.60    16.00   .168+16  .925-08 .295-07  .492+00
     .50    40.00     2.00    80.00   .263+16  .977-11 .104-10  .173-03
     .50    40.00     4.00    80.00   .105+17  .672-11 .870-11  .145-03
     .50    40.00     8.00    80.00   .420+17  .150-11 .478-11  .797-04
    4.00     1.00      .05      .25   .164+13  .150-04 .159-04  .266+03
    4.00     1.00      .10      .25   .657+13  .103-04 .133-04  .222+03
    4.00     1.00      .20      .25   .263+14  .230-05 .733-05  .122+03
    4.00     8.00      .40     2.00   .105+15  .201-06 .214-06  .357+01
    4.00     8.00      .80     2.00   .420+15  .138-06 .179-06  .299+01
    4.00     8.00     1.60     2.00   .168+16  .309-07 .985-07  .164+01
    4.00    40.00     2.00    10.00   .263+16  .405-08 .430-08  .717-01
    4.00    40.00     4.00    10.00   .105+17  .278-08 .360-08  .601-01
    4.00    40.00     8.00    10.00   .420+17  .620-09 .198-08  .330-01
   24.00     1.00      .05      .04   .164+13  .153-04 .162-04  .271+03
   24.00     1.00      .10      .04   .657+13  .105-04 .136-04  .226+03
   24.00     1.00      .20      .04   .263+14  .234-05 .746-05  .124+03
   24.00     8.00      .40      .33   .105+15  .232-06 .247-06  .412+01
   24.00     8.00      .80      .33   .420+15  .160-06 .207-06  .345+01
   24.00     8.00     1.60      .33   .168+16  .357-07 .114-06  .190+01
   24.00    40.00     2.00     1.67   .263+16  .829-08 .882-08  .147+00
   24.00    40.00     4.00     1.67   .105+17  .570-08 .738-08  .123+00
   24.00    40.00     8.00     1.67   .420+17  .127-08 .406-08  .676-01
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Down-current Distribution for LOSS-OF-COOLANT Accident, Batch Release

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RADIONUCLIDE   XE131M
HALF LIFE   .118+02 DAYS
TOTAL RELEASE  .691+00 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .100-09 GRAMS PER CC
MAXIMUM PERMISSIBLE
                                                  .000         .000
DAUGHTER OF PREVIOUS RADIONUCLIDE, DECAY FRACTION =    .0060

 CURRENT    DOWN   RADIUS     TIME    VOLUME    CONCENTRATION AVE.SPEC.
VELOCITY CURRENT                                   ISO-    AVE.  ACTIVITY
  NM/DAY      NM       NM     DAYS          CC   UCI/CC  UCI/CC    UCI/GM
     .50    1.00      .05     2.00   .164+13  .506-07 .538-07  .538+03
     .50    1.00      .10     2.00   .657+13  .348-07 .451-07  .451+03
     .60    1.00      .20     2.00   .263+14  .776-08 .248-07  .248+03
     .50    8.00      .40    16.00   .105+15  .710-09 .756-09  .756+01
     .50    8.00      .80    16.00   .420+15  .488-09 .632-09  .632+01
     .50    8.00     1.60    16.00   .168+16  .109-09 .347-09  .347+01
     .50   40.00     2.00    80.00   .263+16  .126-11 .134-11  .134-01
     .50   40.00     4.00    80.00   .105+17  .867-12 .112-11  .112-01
     .50   40.00     8.00    80.00   .420+17  .193-12 .617-12  .617-02
    4.00    1.00      .05      .25   .164+13  .471-07 .501-07  .501+03
    4.00    1.00      .10      .25   .657+13  .323-07 .419-07  .419+03
    4.00    1.00      .20      .25   .263+14  .722-08 .230-07  .230+03
    4.00    8.00      .40     2.00   .105+15  .791-09 .841-09  .841+01
    4.00    8.00      .80     2.00   .420+15  .543-09 .704-09  .704+01
    4.00    8.00     1.60     2.00   .168+16  .121-09 .387-09  .387+01
    4.00   40.00     2.00    10.00   .263+16  .325-10 .346-10  .346+00
    4.00   40.00     4.00    10.00   .105+17  .224-10 .290-10  .290+00
    4.00   40.00     8.00    10.00   .420+17  .499-11 .159-10  .159+00
   24.00    1.00      .05      .04   .164+13  .465-07 .495-07  .495+03
   24.00    1.00      .10      .04   .657+13  .320-07 .414-07  .414+03
   24.00    1.00      .20      .04   .263+14  .713-08 .228-07  .228+03
   24.00    8.00      .40      .33   .105+15  .738-09 .786-09  .786+01
   24.00    8.00      .80      .33   .420+15  .508-09 .658-09  .658+01
   24.00    8.00     1.60      .33   .168+16  .113-09 .361-09  .361+01
   24.00   40.00     2.00     1.67   .263+16  .313-10 .333-10  .333+00
   24.00   40.00     4.00     1.67   .105+17  .215-10 .279-10  .279+00
   24.00   40.00     8.00     1.67   .420+17  .480-11 .153-10  .153+00
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RADIONUCLIDE   TE 132
HALF LIFE   .324+01 DAYS
TOTAL RELEASE  .133+02 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .000    GRAMS PER CC
MAXIMUM PERMISSIBLE
                                                  .320-06      .730+00

 CURRENT    DOWN   RADIUS     TIME    VOLUME    CONCENTRATION AVE.SPEC.
VELOCITY CURRENT                                   ISO-    AVE.  ACTIVITY
  NM/DAY      NM       NM     DAYS          CC   UCI/CC  UCI/CC    UCI/GM
     .50    1.00      .05     2.00   .164+13  .592-06 .619-06  .000
     .50    1.00      .10     2.00   .657+13  .400-06 .519-06  .000
     .50    1.00      .20     2.00   .263+14  .893-07 .285-06  .000
     .50    8.00      .40    16.00   .105+15  .456-09 .485-09  .000
     .50    8.00      .80    16.00   .420+15  .313-09 .406-09  .000
     .50    8.00     1.60    16.00   .168+16  .699-10 .223-09  .000
     .50   40.00     2.00    80.00   .263+16  .207-16 .220-16  .000
     .50   40.00     4.00    80.00   .105+17  .142-16 .184-16  .000
     .50   40.00     8.00    80.00   .420+17  .317-17 .101-16  .000
    4.00    1.00      .05      .25   .164+13  .847-06 .901-06  .000
    4.00    1.00      .10      .25   .657+13  .582-06 .754-06  .000
    4.00    1.00      .20      .25   .263+14  .130-06 .414-06  .000
    4.00    8.00      .40     2.00   .105+15  .910-09 .969-08  .000
    4.00    8.00      .80     2.00   .420+15  .625-08 .810-08  .000
    4.00    8.00     1.60     2.00   .168+16  .140-08 .445-08  .000
    4.00   40.00     2.00    10.00   .263+16  .658-10 .697-10  .000
    4.00   40.00     4.00    10.00   .105+17  .452-10 .586-10  .000
    4.00   40.00     8.00    10.00   .420+17  .101-10 .322-10  .000
   24.00    1.00      .05      .04   .164+13  .885-06 .942-06  .000
   24.00    1.00      .10      .04   .657+13  .608-06 .788-06  .000
   24.00    1.00      .20      .04   .263+14  .136-06 .433-06  .000
   24.00    8.00      .40      .33   .105+15  .130-07 .139-07  .000
   24.00    8.00      .80      .33   .420+15  .893-09 .116-07  .000
   24.00    8.00     1.60      .33   .168+16  .199-08 .636-08  .000
   24.00   40.00     2.00     1.67   .263+16  .321-09 .416-09  .000
   24.00   40.00     4.00     1.67   .105+17  .269-09 .348-09  .000
   24.00   40.00     8.00     1.67   .420+17  .599-10 .191-09  .000
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Down-current Distribution for LOSS-OF-COOLANT Accident, Batch Release

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RADIONUCLIDE    I 132
HALF LIFE    .942-01 DAYS
TOTAL RELEASE  .341+03 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER   .600-07 GRAMS PER CC
MAXIMUM PERMISSIBLE                                 .000        .110+04
DAUGHTER OF PREVIOUS RADIONUCLIDE, DECAY FRACTION =  1.0000

 CURRENT     DOWN  RADIUS     TIME    VOLUME    CONCENTRATION AVE.SPEC.
VELOCITY  CURRENT                                 ISO-    AVE.  ACTIVITY
  NM/DAY       NM      NM     DAYS        CC    UCI/CC  UCI/CC    UCI/GM
     .50     1.00     .05     2.00   .164+13  .500-06 .638-06   .106+02
     .50     1.00     .10     2.00   .657+13  .412-06 .534-06   .890+01
     .50     1.00     .20     2.00   .263+14  .920-07 .293-06   .489+01
     .50     8.00     .40    16.00   .105+15  .469-09 .499-09   .832-02
     .50     8.00     .80    16.00   .420+15  .322-09 .418-09   .696-02
     .50     8.00    1.60    16.00   .168+16  .719-10 .230-09   .383-02
     .50    40.00    2.00    80.00   .263+16  .213-16 .227-16   .378-09
     .50    40.00    4.00    80.00   .105+17  .146-16 .190-16   .316-09
     .50    40.00    8.00    80.00   .420+17  .327-17 .104-16   .174-09
    4.00     1.00     .05      .25   .164+13  .437-05 .464-05   .774+02
    4.00     1.00     .10      .25   .657+13  .100-05 .389-05   .648+02
    4.00     1.00     .20      .25   .263+14  .670-06 .214-05   .356+02
    4.00     8.00     .40     2.00   .105+15  .937-08 .997-08   .166+00
    4.00     8.00     .80     2.00   .420+15  .644-08 .835-08   .139+00
    4.00     8.00    1.60     2.00   .168+16  .144-08 .459-08   .764-01
    4.00    40.00    2.00    10.00   .263+16  .677-10 .720-10   .120-02
    4.00    40.00    4.00    10.00   .105+17  .465-10 .603-10   .101-02
    4.00    40.00    8.00    10.00   .420+17  .194-10 .331-10   .552-03
   24.00     1.00     .05      .04   .164+13  .171-04 .182-04   .303+03
   24.00     1.00     .10      .04   .657+13  .117-04 .152-04   .254+03
   24.00     1.00     .20      .04   .263+14  .262-05 .836-05   .139+03
   24.00     8.00     .40      .33   .105+15  .430-07 .457-07   .762+00
   24.00     8.00     .80      .33   .420+15  .295-07 .383-07   .638+00
   24.00     8.00    1.60      .33   .168+16  .659-08 .210-07   .350+00
   24.00    40.00    2.00     1.67   .263+16  .403-09 .428-09   .714-02
   24.00    40.00    4.00     1.67   .105+17  .277-09 .359-09   .598-02
   24.00    40.00    8.00     1.67   .420+17  .617-10 .197-09   .328-02
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RADIONUCLIDE    I 133
HALF LIFE    .846+00 DAYS
TOTAL RELEASE  .525+03 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER   .600-07 GRAMS PER CC
MAXIMUM PERMISSIBLE                                 .110-07      .120+03

 CURRENT     DOWN  RADIUS     TIME    VOLUME    CONCENTRATION AVE.SPEC.
VELOCITY  CURRENT                                 ISO-    AVE.  ACTIVITY
  NM/DAY       NM      NM     DAYS        CC    UCI/CC  UCI/CC    UCI/GM
     .50     1.00     .05     2.00   .164+13  .695-05 .729-05   .121+03
     .50     1.00     .10     2.00   .657+13  .471-05 .610-05   .102+03
     .50     1.00     .20     2.00   .263+14  .105-05 .335-05   .559+02
     .50     8.00     .40    16.00   .105+15  .112-11 .129-11   .198-04
     .50     8.00     .80    16.00   .420+15  .769-12 .997-12   .166-04
     .50     8.00    1.60    16.00   .168+16  [illegible] .548-12   .913-05
     .50    40.00    2.00    80.00   .263+16  .764-36 .813-36   .135-28
     .50    40.00    4.00    80.00   .105+17  .525-36 .680-36   .113-28
     .50    40.00    8.00    80.00   .420+17  .117-36 .374-36   .623-29
    4.00     1.00     .05      .25   .164+13  .267-04 .306-04   .509+03
    4.00     1.00     .10      .25   .657+13  .197-04 .256-04   .426+03
    4.00     1.00     .20      .25   .263+14  .441-05 .141-04   .234+03
    4.00     8.00     .40     2.00   .105+15  .107-06 .114-06   .190+01
    4.00     8.00     .80     2.00   .420+15  .736-07 .953-07   .159+01
    4.00     8.00    1.60     2.00   .168+16  .164-07 .524-07   .873+00
    4.00    40.00    2.00    10.00   .263+16  .610-11 .649-11   .108-03
    4.00    40.00    4.00    10.00   .105+17  .420-11 .544-11   .906-04
    4.00    40.00    8.00    10.00   .420+17  .936-12 .299-11   .498-04
   24.00     1.00     .05      .04   .164+13  .341-04 .362-04   .604+03
   24.00     1.00     .10      .04   .657+13  .234-04 .303-04   .506+03
   24.00     1.00     .20      .04   .263+14  .521-05 .167-04   .278+03
   24.00     8.00     .40      .33   .105+15  .419-06 .446-06   .743+01
   24.00     8.00     .80      .33   .420+15  .288-06 .373-06   .622+01
   24.00     8.00    1.60      .33   .168+16  .643-07 .205-06   .342+01
   24.00    40.00    2.00     1.67   .263+16  .563-08 .599-08   .998-01
   24.00    40.00    4.00     1.67   .105+17  .387-08 .501-08   .835-01
   24.00    40.00    8.00     1.67   .420+17  .463-09 .275-08   .459-01
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Down-current Distribution for LOSS-OF-COOLANT Accident, Batch Release

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RADIONUCLIDE   XE133M
HALF LIFE   .226+01 DAYS
TOTAL RELEASE  .535+02 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .100-09 GRAMS PER CC
MAXIMUM PERMISSIBLE                                .000         .000
DAUGHTER OF PREVIOUS RADIONUCLIDE, DECAY FRACTION =  1.0000

 CURRENT     DOWN   RADIUS     TIME    VOLUME     CONCENTRATION AVE.SPEC.
VELOCITY CURRENT                                     ISO-    AVE.  ACTIVITY
  NM/DAY      NM        NM     DAYS         CC   UCI/CC   UCI/CC    UCI/GM
     .50    1.00       .05     2.00   .164+13  .927-05  .986-05   .986+05
     .50    1.00       .10     2.00   .657+13  .637-05  .826-05   .826+05
     .50    1.00       .20     2.00   .263+14  .142-05  .454-05   .454+05
     .50    8.00       .40    16.00   .105+15  .285-08  .304-08   .304+02
     .50    8.00       .80    16.00   .420+15  .196-08  .254-08   .254+02
     .50    8.00      1.60    16.00   .168+16  .438-09  .140-08   .140+02
     .50   40.00      2.00    80.00   .263+16  .343-18  .364-18   .364-08
     .50   40.00      4.00    80.00   .105+17  .235-18  .305-18   .305-08
     .50   40.00      8.00    80.00   .420+17  .525-19  .168-18   .168-08
    4.00    1.00       .05      .25   .164+13  .568-05  .604-05   .604+05
    4.00    1.00       .10      .25   .657+13  .390-05  .506-05   .506+05
    4.00    1.00       .20      .25   .263+14  .871-06  .278-05   .278+05
    4.00    8.00       .40     2.00   .105+15  .145-06  .154-06   .154+04
    4.00    8.00       .80     2.00   .420+15  .996-07  .129-06   .129+04
    4.00    8.00      1.60     2.00   .168+16  .222-07  .709-07   .709+03
    4.00   40.00      2.00    10.00   .263+16  .715-09  .761-09   .761+01
    4.00   40.00      4.00    10.00   .105+17  .492-09  .637-09   .637+01
    4.00   40.00      8.00    10.00   .420+17  .110-09  .350-09   .350+01
   24.00    1.00       .05      .04   .164+13  .399-05  .424-05   .424+05
   24.00    1.00       .10      .04   .657+13  .274-05  .355-05   .355+05
   24.00    1.00       .20      .04   .263+14  .611-06  .195-05   .195+05
   24.00    8.00       .40      .33   .105+15  .974-07  .104-06   .104+04
   24.00    8.00       .80      .33   .420+15  .670-07  .868-07   .868+03
   24.00    8.00      1.60      .33   .168+16  .149-07  .477-07   .477+03
   24.00   40.00      2.00     1.67   .263+16  .589-08  .627-08   .627+02
   24.00   40.00      4.00     1.67   .105+17  .405-08  .524-08   .524+02
   24.00   40.00      8.00     1.67   .420+17  .903-09  .288-08   .288+02
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RADIONUCLIDE   XE 133
HALF LIFE   .527+01 DAYS
TOTAL RELEASE  .210+04 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .100-09 GRAMS PER CC
MAXIMUM PERMISSIBLE                                .000         .000
DAUGHTER OF PREVIOUS RADIONUCLIDE, DECAY FRACTION =  1.0000

 CURRENT     DOWN   RADIUS     TIME    VOLUME     CONCENTRATION AVE.SPEC.
VELOCITY CURRENT                                     ISO-    AVE.  ACTIVITY
  NM/DAY      NM        NM     DAYS         CC   UCI/CC   UCI/CC    UCI/GM
     .50    1.00       .05     2.00   .164+13  .112-03  .117-03   .117+07
     .50    1.00       .10     2.00   .657+13  .758-04  .982-04   .982+06
     .50    1.00       .20     2.00   .263+14  .149-04  .540-04   .540+06
     .50    8.00       .40    16.00   .105+15  .224-06  .313-06   .313+04
     .50    8.00       .80    16.00   .420+15  .202-06  .262-06   .262+04
     .50    8.00      1.60    16.00   .168+16  .451-07  .144-06   .144+04
     .50   40.00      2.00    80.00   .263+16  .262-11  .279-11   .279-01
     .50   40.00      4.00    80.00   .105+17  .180-11  .234-11   .234-01
     .50   40.00      8.00    80.00   .420+17  .402-12  .128-11   .128-01
    4.00    1.00       .05      .25   .164+13  .137-03  .145-03   .145+07
    4.00    1.00       .10      .25   .657+13  .439-04  .122-03   .122+07
    4.00    1.00       .20      .25   .263+14  .210-04  .668-04   .668+06
    4.00    8.00       .40     2.00   .105+15  .172-05  .183-05   .183+05
    4.00    8.00       .80     2.00   .420+15  .114-05  .153-05   .153+05
    4.00    8.00      1.60     2.00   .168+16  .264-06  .843-06   .843+04
    4.00   40.00      2.00    10.00   .263+16  .256-07  .272-07   .272+03
    4.00   40.00      4.00    10.00   .105+17  .174-07  .228-07   .228+03
    4.00   40.00      8.00    10.00   .420+17  .392-08  .125-07   .125+03
   24.00    1.00       .05      .04   .164+13  .140-03  .149-03   .149+07
   24.00    1.00       .10      .04   .657+13  .964-04  .125-03   .125+07
   24.00    1.00       .20      .04   .263+14  .215-04  .686-04   .686+06
   24.00    8.00       .40      .33   .105+15  .211-05  .225-05   .225+05
   24.00    8.00       .80      .33   .420+15  .145-05  .188-05   .188+05
   24.00    8.00      1.60      .33   .168+16  .324-06  .103-05   .103+05
   24.00   40.00      2.00     1.67   .263+16  .718-07  .763-07   .763+03
   24.00   40.00      4.00     1.67   .105+17  .493-07  .639-07   .639+03
   24.00   40.00      8.00     1.67   .420+17  .110-07  .351-07   .351+03
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Down-current Distribution for LOSS-OF-COOLANT Accident, Batch Release

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RADIONUCLIDE   TE 134
HALF LIFE   .292-01 DAYS
TOTAL RELEASE  .215+02 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .000   GRAMS PER CC
MAXIMUM PERMISSIBLE                                 .000      .000

 CURRENT     DOWN  RADIUS     TIME    VOLUME   CONCENTRATION AVE.SPEC.
VELOCITY CURRENT                                 ISO-   AVE.  ACTIVITY
  NM/DAY      NM      NM     DAYS         CC   UCI/CC UCI/CC    UCI/GM
     .50    1.00     .05     2.00   .164+13  .351-26 .373-26   .000
     .50    1.00     .10     2.00   .657+13  .241-26 .313-26   .000
     .50    1.00     .20     2.00   .263+14  .538-27 .172-26   .000
     .50    8.00     .40    16.00   .105+15  .000    .000      .000
     .50    8.00     .80    16.00   .420+15  .000    .000      .000
     .50    8.00    1.60    16.00   .168+16  .000    .000      .000
     .50   40.00    2.00    80.00   .263+16  .000    .000      .000
     .50   40.00    4.00    80.00   .105+17  .000    .000      .000
     .50   40.00    8.00    80.00   .420+17  .000    .000      .000
    4.00    1.00     .05      .25   .164+13  .383-08 .407-08   .000
    4.00    1.00     .10      .25   .657+13  .263-08 .341-08   .000
    4.00    1.00     .20      .25   .263+14  .587-09 .187-08   .000
    4.00    8.00     .40     2.00   .105+15  .549-28 .584-28   .000
    4.00    8.00     .60     2.00   .420+15  .377-28 .489-28   .000
    4.00    8.00    1.60     2.00   .168+16  .841-29 .268-28   .000
    4.00   40.00    2.00    10.00   .263+16  .000    .000      .000
    4.00   40.00    4.00    10.00   .105+17  .000    .000      .000
    4.00   40.00    8.00    10.00   .420+17  .000    .000      .000
   24.00    1.00     .05      .04   .164+13  .537-06 .571-06   .000
   24.00    1.00     .10      .04   .657+13  .349-06 .478-06   .000
   24.00    1.00     .20      .04   .263+14  .824-07 .263-06   .000
   24.00    8.00     .40      .33   .105+15  .827-11 .880-11   .000
   24.00    8.00     .80      .33   .420+15  .569-11 .737-11   .000
   24.00    8.00    1.60      .33   .168+16  .127-11 .905-11   .000
   24.00   40.00    2.00     1.67   .263+16  .598-26 .637-26   .000
   24.00   40.00    4.00     1.67   .105+17  .411-26 .533-26   .000
   24.00   40.00    8.00     1.67   .420+17  .918-27 .293-26   .000
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RADIONUCLIDE   I 134
HALF LIFE   .361-01 DAYS
TOTAL RELEASE  .614+03 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .600-07 GRAMS PER CC
MAXIMUM PERMISSIBLE                                 .160-06      .190+04
DAUGHTER OF PREVIOUS RADIONUCLIDE, DECAY FRACTION =  1.0000

 CURRENT     DOWN  RADIUS     TIME    VOLUME   CONCENTRATION AVE.SPEC.
VELOCITY CURRENT                                 ISO-   AVE.  ACTIVITY
  NM/DAY      NM      NM     DAYS         CC   UCI/CC UCI/CC    UCI/GM
     .50    1.00     .05     2.00   .164+13  .100-20 .107-20  .178-13
     .50    1.00     .10     2.00   .657+13  .649-21 .893-21  .149-13
     .50    1.00     .20     2.00   .263+14  .154-21 .491-21  .818-14
     .50    8.00     .40    16.00   .105+15  .000    .000     .000
     .50    8.00     .80    16.00   .420+15  .000    .000     .000
     .50    8.00    1.60    16.00   .168+16  .000    .000     .000
     .50   40.00    2.00    80.00   .263+16  .000    .000     .000
     .50   40.00    4.00    80.00   .105+17  .000    .000     .000
     .50   40.00    8.00    80.00   .420+17  .000    .000     .000
    4.00    1.00     .05      .25   .164+13  .374-06 .398-06  .663+01
    4.00    1.00     .10      .25   .657+13  .257-06 .333-06  .555+01
    4.00    1.00     .20      .25   .263+14  .573-07 .183-06  .305+01
    4.00    8.00     .40     2.00   .105+15  .157-22 .167-22  .278-15
    4.00    8.00     .80     2.00   .420+15  .104-22 .140-22  .233-15
    4.00    8.00    1.60     2.00   .168+16  .240-23 .767-23  .128-15
    4.00   40.00    2.00    10.00   .263+16  .000    .000     .000
    4.00   40.00    4.00    10.00   .105+17  .000    .000     .000
    4.00   40.00    8.00    10.00   .420+17  .000    .000     .000
   24.00    1.00     .05      .04   .164+13  .190-04 .202-04  .337+03
   24.00    1.00     .10      .04   .657+13  .131-04 .169-04  .282+03
   24.00    1.00     .20      .04   .263+14  .291-05 .930-05  .155+03
   24.00    8.00     .40      .33   .105+15  .120-04 .127-08  .212-01
   24.00    8.00     .80      .33   .420+15  .422-09 .106-08  .177-01
   24.00    8.00    1.60      .33   .168+16  .183-09 .585-09  .975-02
   24.00   40.00    2.00     1.67   .263+16  .377-21 .491-21  .668-14
   24.00   40.00    4.00     1.67   .105+17  .259-21 .336-21  .559-14
   24.00   40.00    8.00     1.67   .420+17  .578-22 .184-21  .307-14
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Down-current Distribution for LOSS-OF-COOLANT Accident, Batch Release

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RADIONUCLIDE   CS 134
HALF LIFE   .748+03 DAYS
TOTAL RELEASE  .200+03 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .380-03 GRAMS PER CC
MAXIMUM PERMISSIBLE                                 .200-06      .150-01

 CURRENT     DOWN   RADIUS     TIME    VOLUME    CONCENTRATION AVE.SPEC.
VELOCITY  CURRENT                                  ISO-    AVE.  ACTIVITY
  NM/DAY      NM       NM      DAYS         CC   UCI/CC  UCI/CC    UCI/GM
     .50    1.00      .05      2.00   .164+13  .134-07 .143-07   .375-04
     .50    1.00      .10      2.00   .657+13  .721-08 .119-07   .314-04
     .50    1.00      .20      2.00   .263+14  .206-08 .656-08   .173-04
     .50    8.00      .40     16.00   .105+15  .207-09 .220-09   .579-06
     .50    8.00      .80     16.00   .420+15  .142-09 .184-09   .485-06
     .50    9.00     1.60     16.00   .168+16  .317-10 .101-09   .266-06
     .50   40.00     2.00     80.00   .263+16  .780-11 .829-11   .218-07
     .50   40.00     4.00     80.00   .105+17  .536-11 .694-11   .183-07
     .50   40.00     8.00     80.00   .420+17  .120-11 .381-11   .100-07
    4.00    1.00      .05       .25   .164+13  .134-07 .143-07   .376-04
    4.00    1.00      .10       .25   .657+13  .923-08 .120-07   .315-04
    4.00    1.00      .20       .25   .263+14  .206-08 .657-08   .173-04
    4.00    8.00      .40      2.00   .105+15  .207-09 .223-09   .586-06
    4.00    8.00      .80      2.00   .420+15  .144-09 .187-09   .491-06
    4.00    8.00     1.60      2.00   .168+16  .321-10 .102-09   .270-06
    4.00   40.00     2.00     10.00   .263+16  .832-11 .885-11   .233-07
    4.00   40.00     4.00     10.00   .105+17  .572-11 .741-11   .195-07
    4.00   40.00     8.00     10.00   .420+17  .128-11 .407-11   .107-07
   24.00    1.00      .05       .04   .164+13  .134-07 .143-07   .376-04
   24.00    1.00      .10       .04   .657+13  .923-08 .120-07   .315-04
   24.00    1.00      .20       .04   .263+14  .206-08 .657-08   .173-04
   24.00    8.00      .40       .33   .105+15  .210-09 .223-09   .587-06
   24.00    8.00      .80       .33   .420+15  .144-09 .187-09   .492-06
   24.00    8.00     1.60       .33   .168+16  .322-10 .103-09   .270-06
   24.00   40.00     2.00      1.67   .263+16  .838-11 .892-11   .235-07
   24.00   40.00     4.00      1.67   .105+17  .576-11 .746-11   .196-07
   24.00   40.00     8.00      1.67   .420+17  .129-11 .410-11   .108-07
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RADIONUCLIDE   I 135
HALF LIFE   .278+00 DAYS
TOTAL RELEASE  .484+03 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .600-07 GRAMS PER CC
MAXIMUM PERMISSIBLE                                 .320-07      .370+03

 CURRENT     DOWN   RADIUS     TIME    VOLUME    CONCENTRATION AVE.SPEC.
VELOCITY  CURRENT                                  ISO-    AVE.  ACTIVITY
  NM/DAY      NM       NM      DAYS         CC   UCI/CC  UCI/CC    UCI/GM
     .50    1.00      .05      2.00   .164+13  .222-06 .236-06   .394+01
     .50    1.00      .10      2.00   .657+13  .153-06 .198-06   .330+01
     .50    1.00      .20      2.00   .263+14  .341-07 .109-06   .181+01
     .50    8.00      .40     16.00   .105+15  .242-23 .258-23   .429-16
     .50    8.00      .60     16.00   .420+15  .166-23 .216-23   .359-16
     .50    8.00     1.60     16.00   .168+16  .371-24 .118-23   .197-16
     .50   40.00     2.00     80.00   .263+16  .000    .000      .000
     .50   40.00     4.00     80.00   .105+17  .000    .000      .000
     .50   40.00     8.00     80.00   .420+17  .000    .000      .000
    4.00    1.00      .05       .25   .164+13  .174-04 .185-04   .309+03
    4.00    1.00      .10       .25   .657+13  .120-04 .155-04   .259+03
    4.00    1.00      .20       .25   .263+14  .267-05 .853-05   .142+03
    4.00    8.00      .40      2.00   .105+15  .347-08 .369-08   .616-01
    4.00    8.00      .80      2.00   .420+15  .239-08 .309-08   .515-01
    4.00    8.00     1.60      2.00   .168+16  .532-09 .170-08   .283-01
    4.00   40.00     2.00     10.00   .263+16  .303-18 .323-18   .538-11
    4.00   40.00     4.00     10.00   .105+17  .204-18 .270-18   .450-11
    4.00   40.00     8.00     10.00   .420+17  .465-19 .148-18   .247-11
   24.00    1.00      .05       .04   .164+13  .293-04 .312-04   .519+03
   24.00    1.00      .10       .04   .657+13  .201-04 .261-04   .435+03
   24.00    1.00      .20       .04   .263+14  .449-05 .143-04   .239+03
   24.00    8.00      .40       .33   .105+15  .221-06 .235-06   .392+01
   24.00    8.00      .80       .33   .420+15  .152-06 .197-06   .328+01
   24.00    8.00     1.60       .33   .168+16  .334-07 .108-06   .180+01
   24.00   40.00     2.00      1.67   .263+16  .319-09 .339-09   .565-02
   24.00   40.00     4.00      1.67   .105+17  .219-09 .284-09   .473-02
   24.00   40.00     8.00      1.67   .420+17  .499-10 .156-09   .260-02
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Down-current Distribution for LOSS-OF-COOLANT Accident, Batch Release

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RADIONUCLIDE   XE 135
HALF LIFE   .381+00 DAYS
TOTAL RELEASE  .455+03 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .100-09 GRAMS PER CC
MAXIMUM PERMISSIBLE                                .000        .000
DAUGHTER OF PREVIOUS RADIONUCLIDE, DECAY FRACTION =  1.0000

 CURRENT     DOWN   RADIUS      TIME    VOLUME     CONCENTRATION AVE.SPEC.
VELOCITY  CURRENT                                    ISO-     AVE.  ACTIVITY
  NM/DAY       NM       NM      DAYS         CC    UCI/CC   UCI/CC    UCI/GM
     .50     1.00      .05      2.00   .164+13   .251-05  .267-05   .267+05
     .50     1.00      .10      2.00   .657+13   .173-05  .224-05   .224+05
     .50     1.00      .20      2.00   .263+14   .385-06  .123-05   .123+05
     .50     8.00      .40     16.00   .105+15   .424-18  .451-18   .451-08
     .50     8.00      .80     16.00   .420+15   .292-18  .378-18   .378-08
     .50     8.00     1.60     16.00   .168+16   .651-19  .208-18   .208-08
     .50    40.00     2.00     80.00   .263+16   .000     .000      .000
     .50    40.00     4.00     80.00   .105+17   .000     .000      .000
     .50    40.00     8.00     80.00   .420+17   .000     .000      .000
    4.00     1.00      .05       .25   .164+13   .240-04  .298-04   .298+06
    4.00     1.00      .10       .25   .657+13   .193-04  .250-04   .250+06
    4.00     1.00      .20       .25   .263+14   .430-05  .137-04   .137+06
    4.00     8.00      .40      2.00   .105+15   .393-07  .418-07   .418+03
    4.00     8.00      .80      2.00   .420+15   .270-07  .350-07   .350+03
    4.00     8.00     1.60      2.00   .168+16   .602-08  .192-07   .192+03
    4.00    40.00     2.00     10.00   .263+16   .931-15  .991-15   .991-05
    4.00    40.00     4.00     10.00   .105+17   .640-15  .829-15   .829-05
    4.00    40.00     8.00     10.00   .420+17   .143-15  .456-15   .456-05
   24.00     1.00      .05       .04   .164+13   .376-04  .325-04   .325+06
   24.00     1.00      .10       .04   .657+13   .210-04  .272-04   .272+06
   24.00     1.00      .20       .04   .263+14   .469-05  .150-04   .150+06
   24.00     8.00      .40       .33   .105+15   .411-06  .437-06   .437+04
   24.00     8.00      .80       .33   .420+15   .292-06  .366-06   .366+04
   24.00     8.00     1.60       .33   .168+16   .630-07  .201-06   .201+04
   24.00    40.00     2.00      1.67   .263+16   .271-09  .288-08   .288+02
   24.00    40.00     4.00      1.67   .105+17   .146-08  .241-08   .241+02
   24.00    40.00     8.00      1.67   .420+17   .415-09  .132-08   .132+02
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RADIONUCLIDE   CS 136
HALF LIFE   .137+02 DAYS
TOTAL RELEASE  .112-01 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .380-03 GRAMS PER CC
MAXIMUM PERMISSIBLE
                                                .600-05     .140+00

 CURRENT     DOWN   RADIUS      TIME    VOLUME     CONCENTRATION AVE.SPEC.
VELOCITY  CURRENT                                    ISO-     AVE.  ACTIVITY
  NM/DAY       NM       NM      DAYS         CC    UCI/CC   UCI/CC    UCI/GM
     .50     1.00      .05      2.00   .164+13   .690-09  .723-09   .190-05
     .50     1.00      .10      2.00   .657+13   .467-09  .605-09   .159-05
     .50     1.00      .20      2.00   .263+14   .104-09  .333-09   .875-06
     .50     8.00      .40     16.00   .105+15   .523-11  .557-11   .146-07
     .50     8.00      .80     16.00   .420+15   .340-11  .466-11   .123-07
     .50     8.00     1.60     16.00   .168+16   .802-12  .256-11   .674-08
     .50    40.00     2.00     80.00   .263+16   .822-14  .874-14   .230-10
     .50    40.00     4.00     80.00   .105+17   .565-14  .732-14   .193-10
     .50    40.00     8.00     80.00   .420+17   .126-14  .402-14   .106-10
    4.00     1.00      .05       .25   .164+13   .743-09  .790-09   .208-05
    4.00     1.00      .10       .25   .657+13   .510-09  .661-09   .174-05
    4.00     1.00      .20       .25   .263+14   .114-09  .363-09   .956-06
    4.00     8.00      .40      2.00   .105+15   .106-10  .113-10   .297-07
    4.00     8.00      .80      2.00   .420+15   .730-11  .946-11   .249-07
    4.00     8.00     1.60      2.00   .168+16   .163-11  .520-11   .137-07
    4.00    40.00     2.00     10.00   .263+16   .283-12  .302-12   .794-09
    4.00    40.00     4.00     10.00   .105+17   .195-12  .252-12   .664-09
    4.00    40.00     8.00     10.00   .420+17   .435-13  .139-12   .365-09
   24.00     1.00      .05       .04   .164+13   .751-09  .798-09   .210-05
   24.00     1.00      .10       .04   .657+13   .516-09  .668-09   .176-05
   24.00     1.00      .20       .04   .263+14   .115-09  .367-09   .964-06
   24.00     8.00      .40       .33   .105+15   .116-10  .123-10   .324-07
   24.00     8.00      .80       .33   .420+15   .794-11  .103-10   .271-07
   24.00     8.00     1.60       .33   .168+16   .177-11  .565-11   .149-07
   24.00    40.00     2.00      1.67   .263+16   .432-12  .460-12   .121-08
   24.00    40.00     4.00      1.67   .105+17   .297-12  .385-12   .101-08
   24.00    40.00     8.00      1.67   .420+17   .663-13  .211-12   .556-09
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Down-current Distribution for LOSS-OF-COOLANT Accident, Batch Release

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RADIONUCLIDE    CS 137
HALF LIFE    .109+05 DAYS
TOTAL RELEASE   .871+00 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER   .380-03 GRAMS PER CC
MAXIMUM PERMISSIBLE
                                                   .200-05      .210-01

 CURRENT     DOWN   RADIUS      TIME     VOLUME    CONCENTRATION AVE.SPEC.
VELOCITY  CURRENT                                     ISO-     AVE.   ACTIVITY
 NM/DAY       NM        NM      DAYS         CC     UCI/CC   UCI/CC    UCI/GM
     .50     1.00       .05     2.00    .164+13   .585-07  .622-07   .164-03
     .50     1.00       .10     2.00    .657+13   .402-07  .521-07   .137-03
     .50     1.00       .20     2.00    .263+14   .497-08  .286-07   .753-04
     .50     8.00       .40    16.00    .105+15   .913-09  .971-09   .256-05
     .50     8.00       .80    16.00    .420+15   .628-09  .813-09   .214-05
     .50     8.00      1.60    16.00    .168+16   .140-09  .447-09   .118-05
     .50    40.00      2.00    80.00    .263+16   .344-10  .387-10   .102-06
     .50    40.00      4.00    80.00    .105+17   .250-10  .324-10   .852-07
     .50    40.00      8.00    80.00    .420+17   .558-11  .178-10   .468-07
    4.00     1.00       .05      .25    .164+13   .585-07  .622-07   .164-03
    4.00     1.00       .10      .25    .657+13   .402-07  .521-07   .137-03
    4.00     1.00       .20      .25    .263+14   .497-08  .286-07   .753-04
    4.00     8.00       .40     2.00    .105+15   .914-09  .972-09   .256-05
    4.00     8.00       .80     2.00    .420+15   .628-09  .814-09   .214-05
    4.00     8.00      1.60     2.00    .168+16   .140-09  .447-09   .118-05
    4.00    40.00      2.00    10.00    .263+16   .365-10  .389-10   .102-06
    4.00    40.00      4.00    10.00    .105+17   .251-10  .325-10   .856-07
    4.00    40.00      8.00    10.00    .420+17   .560-11  .179-10   .470-07
   24.00     1.00       .05      .04    .164+13   .585-07  .622-07   .164-03
   24.00     1.00       .10      .04    .657+13   .402-07  .521-07   .137-03
   24.00     1.00       .20      .04    .263+14   .497-08  .286-07   .753-04
   24.00     8.00       .40      .33    .105+15   .914-09  .972-09   .256-05
   24.00     8.00       .80      .33    .420+15   .628-09  .814-09   .214-05
   24.00     8.00      1.60      .33    .168+16   .140-09  .447-09   .118-05
   24.00    40.00      2.00     1.67    .263+16   .366-10  .389-10   .102-06
   24.00    40.00      4.00     1.67    .105+17   .251-10  .326-10   .857-07
   24.00    40.00      8.00     1.67    .420+17   .561-11  .179-10   .471-07
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RADIONUCLIDE    XE 138
HALF LIFE    .122-01 DAYS
TOTAL RELEASE   .165+04 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER   .100-09 GRAMS PER CC
MAXIMUM PERMISSIBLE
                                                    .000         .000

 CURRENT     DOWN   RADIUS      TIME     VOLUME    CONCENTRATION AVE.SPEC.
VELOCITY  CURRENT                                     ISO-     AVE.   ACTIVITY
 NM/DAY       NM        NM      DAYS         CC     UCI/CC   UCI/CC    UCI/GM
     .50     1.00       .05     2.00    .164+13   .000      .000      .000
     .50     1.00       .10     2.00    .657+13   .000      .000      .000
     .50     1.00       .20     2.00    .263+14   .000      .000      .000
     .50     8.00       .40    16.00    .105+15   .000      .000      .000
     .50     8.00       .80    16.00    .420+15   .000      .000      .000
     .50     8.00      1.60    16.00    .168+16   .000      .000      .000
     .50    40.00      2.00    80.00    .263+16   .000      .000      .000
     .50    40.00      4.00    80.00    .105+17   .000      .000      .000
     .50    40.00      8.00    80.00    .420+17   .000      .000      .000
    4.00     1.00       .05      .25    .164+13   .445-11  .899-10   .899+00
    4.00     1.00       .10      .25    .657+13   .561-10  .753-10   .753+00
    4.00     1.00       .20      .25    .263+14   .130-10  .413-10   .413+00
    4.00     8.00       .40     2.00    .105+15   .000      .000      .000
    4.00     8.00       .80     2.00    .420+15   .000      .000      .000
    4.00     8.00      1.60     2.00    .168+16   .000      .000      .000
    4.00    40.00      2.00    10.00    .263+16   .000      .000      .000
    4.00    40.00      4.00    10.00    .105+17   .000      .000      .000
    4.00    40.00      8.00    10.00    .420+17   .000      .000      .000
   24.00     1.00       .05      .04    .164+13   .117-04  .124-04   .124+06
   24.00     1.00       .10      .04    .657+13   .801-05  .104-04   .104+06
   24.00     1.00       .20      .04    .263+14   .177-05  .570-05   .570+05
   24.00     8.00       .40      .33    .105+15   .116-13  .124-13   .124-03
   24.00     8.00       .80      .33    .420+15   .798-14  .103-13   .103-03
   24.00     8.00      1.60      .33    .168+16   .178-14  .568-14   .568-04
   24.00    40.00      2.00     1.67    .263+16   .000      .000      .000
   24.00    40.00      4.00     1.67    .105+17   .000      .000      .000
   24.00    40.00      8.00     1.67    .420+17   .000      .000      .000
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Down-current Distribution for LOSS-OF-COOLANT Accident, Batch Release

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RADIONUCLIDE   CS 138
HALF LIFE   .224-01 DAYS
TOTAL RELEASE  .210+02 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .380-03 GRAMS PER CC
MAXIMUM PERMISSIBLE                                 .000       .000
DAUGHTER OF PREVIOUS RADIONUCLIDE, DECAY FRACTION =  1.0000

 CURRENT    DOWN  RADIUS     TIME    VOLUME    CONCENTRATION AVE.SPEC.
VELOCITY CURRENT                                 ISO-    AVE.  ACTIVITY
  NM/DAY      NM      NM     DAYS        CC    UCI/CC  UCI/CC    UCI/GM
     .50    1.00     .05     2.00   .164+13   .201-30 .214-30   .564-27
     .50    1.00     .10     2.00   .657+13   .138-30 .179-30   .472-27
     .50    1.00     .20     2.00   .263+14   .309-3  .986-31   .259-27
     .50    8.00     .40    16.00   .105+15   .000    .000      .000
     .50    8.00     .80    16.00   .420+15   .000    .000      .000
     .50    8.00    1.60    16.00   .168+16   .000    .000      .000
     .50   40.00    2.00    80.00   .263+16   .000    .000      .000
     .50   40.00    4.00    80.00   .105+17   .000    .000      .000
     .50   40.00    8.00    80.00   .420+17   .000    .000      .000
    4.00    1.00     .05      .25   .164+13   .655-07 .697-07   .183-03
    4.00    1.00     .10      .25   .657+13   .450-07 .584-07   .154-03
    4.00    1.00     .20      .25   .263+14   .100-07 .321-07   .844-04
    4.00    8.00     .40     2.00   .105+15   .315-32 .335-32   .881-29
    4.00    8.00     .80     2.00   .420+15   .216-32 .280-32   .738-29
    4.00    8.00    1.60     2.00   .168+16   .483-33 .154-32   .405-29
    4.00   40.00    2.00    10.00   .263+16   .000    .000      .000
    4.00   40.00    4.00    10.00   .105+17   .000    .000      .000
    4.00   40.00    8.00    10.00   .420+17   .000    .000      .000
   24.00    1.00     .05      .04   .164+13   .274-04 .291-04   .767-01
   24.00    1.00     .10      .04   .657+13   .188-04 .244-04   .642-01
   24.00    1.00     .20      .04   .263+14   .420-05 .134-04   .353-01
   24.00    8.00     .40      .33   .105+15   .778-10 .828-10   .218-06
   24.00    8.00     .80      .33   .420+15   .535-10 .693-10   .182-06
   24.00    8.00    1.60      .33   .168+16   .119-10 .381-10   .100-06
   24.00   40.00    2.00     1.67   .263+16   .379-29 .403-29   .106-25
   24.00   40.00    4.00     1.67   .105+17   .261-29 .338-29   .888-26
   24.00   40.00    8.00     1.67   .420+17   .581-30 .185-29   .488-26


RADIONUCLIDE   BA 140
HALF LIFE   .128+02 DAYS
TOTAL RELEASE  .197+02 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .300-07 GRAMS PER CC
MAXIMUM PERMISSIBLE                                 .320-05    .150+03

 CURRENT    DOWN  RADIUS     TIME    VOLUME    CONCENTRATION AVE.SPEC.
VELOCITY CURRENT                                 ISO-    AVE.  ACTIVITY
  NM/DAY      NM      NM     DAYS        CC    UCI/CC  UCI/CC    UCI/GM
     .50    1.00     .05     2.00   .164+13   .119-05 .126-05   .421+02
     .50    1.00     .10     2.00   .657+13   .816-06 .106-05   .352+02
     .50    1.00     .20     2.00   .263+14   .182-06 .581-06   .194+02
     .50    8.00     .40    16.00   .105+15   .869-08 .925-08   .309+00
     .50    8.00     .80    16.00   .420+15   .597-08 .774-08   .258+00
     .50    8.00    1.60    16.00   .168+16   .133-08 .425-08   .142+00
     .50   40.00    2.00    80.00   .263+16   .109-10 .116-10   .386-03
     .50   40.00    4.00    80.00   .105+17   .747-11 .968-11   .323-03
     .50   40.00    8.00    80.00   .420+17   .167-11 .532-11   .177-03
    4.00    1.00     .05      .25   .164+13   .131-05 .139-05   .463+02
    4.00    1.00     .10      .25   .657+13   .897-06 .116-05   .387+02
    4.00    1.00     .20      .25   .263+14   .200-06 .639-06   .213+02
    4.00    8.00     .40     2.00   .105+15   .186-07 .197-07   .658+00
    4.00    8.00     .80     2.00   .420+15   .127-07 .165-07   .551+00
    4.00    8.00    1.60     2.00   .168+16   .284-08 .908-08   .303+00
    4.00   40.00    2.00    10.00   .263+16   .481-09 .512-09   .171-01
    4.00   40.00    4.00    10.00   .105+17   .331-09 .429-09   .143-01
    4.00   40.00    8.00    10.00   .420+17   .738-10 .235-09   .785-02
   24.00    1.00     .05      .04   .164+13   .132-05 .140-05   .468+02
   24.00    1.00     .10      .04   .657+13   .907-06 .118-05   .392+02
   24.00    1.00     .20      .04   .263+14   .202-06 .646-06   .215+02
   24.00    8.00     .40      .33   .105+15   .203-07 .216-07   .720+00
   24.00    8.00     .80      .33   .420+15   .140-07 .181-07   .603+00
   24.00    8.00    1.60      .33   .168+16   .311-08 .993-08   .331+00
   24.00   40.00    2.00     1.67   .263+16   .756-09 .804-09   .268-01
   24.00   40.00    4.00     1.67   .105+17   .519-09 .673-09   .224-01
   24.00   40.00    8.00     1.67   .420+17   .116-09 .370-09   .123-01
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Down-current Distribution for LOSS-OF-COOLANT Accident, Batch Release

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RADIONUCLIDE    LA 140
HALF LIFE    .168+01 DAYS
TOTAL RELEASE   .198+02 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .300-09 GRAMS PER CC
MAXIMUM PERMISSIBLE                                    .380-06      .480+04
DAUGHTER OF PREVIOUS RADIONUCLIDE, DECAY FRACTION =  1.0000

 CURRENT     DOWN   RADIUS     TIME     VOLUME     CONCENTRATION AVE.SPEC.
VELOCITY  CURRENT                                    ISO-    AVE.   ACTIVITY
  NM/DAY       NM       NM     DAYS         CC    UCI/CC  UCI/CC     UCI/GM
     .50     1.00      .05     2.00   .164+13  .128-05 .136-05   .455+04
     .50     1.00      .10     2.00   .657+13  .881-06 .114-05   .381+04
     .50     1.00      .20     2.00   .263+14  .197-06 .627-06   .209+04
     .50     8.00      .40    16.00   .105+15  .100-07 .106-07   .355+02
     .50     8.00      .80    16.00   .420+15  .667-08 .890-08   .297+02
     .50     8.00     1.60    16.00   .168+16  .153-08 .489-08   .163+02
     .50    40.00     2.00    80.00   .263+16  .125-10 .133-10   .444-01
     .50    40.00     4.00    80.00   .105+17  .960-11 .111-10   .371-01
     .50    40.00     8.00    80.00   .420+17  .192-11 .612-11   .204-01
    4.00     1.00      .05      .25   .164+13  .133-05 .141-05   .471+04
    4.00     1.00      .10      .25   .657+13  .913-06 .118-05   .394+04
    4.00     1.00      .20      .25   .263+14  .204-06 .650-06   .217+04
    4.00     8.00      .40     2.00   .105+15  .200-07 .213-07   .710+02
    4.00     8.00      .80     2.00   .420+15  .138-07 .178-07   .595+02
    4.00     8.00     1.60     2.00   .168+16  .307-08 .980-08   .327+02
    4.00    40.00     2.00    10.00   .263+16  .552-09 .587-09   .196+01
    4.00    40.00     4.00    10.00   .105+17  .379-09 .491-09   .164+01
    4.00    40.00     8.00    10.00   .420+17  .846-10 .270-09   .900+00
   24.00     1.00      .05      .04   .164+13  .133-05 .141-05   .471+04
   24.00     1.00      .10      .04   .657+13  .914-06 .118-05   .395+04
   24.00     1.00      .20      .04   .263+14  .204-06 .651-06   .217+04
   24.00     8.00      .40      .33   .105+15  .207-07 .221-07   .735+02
   24.00     8.00      .80      .33   .420+15  .143-07 .185-07   .616+02
   24.00     8.00     1.60      .33   .168+16  .318-08 .101-07   .338+02
   24.00    40.00     2.00     1.67   .263+16  .809-09 .861-09   .287+01
   24.00    40.00     4.00     1.67   .105+17  .556-09 .720-09   .240+01
   24.00    40.00     8.00     1.67   .420+17  .124-09 .396-09   .132+01
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RADIONUCLIDE    PR 143
HALF LIFE    .136+02 DAYS
TOTAL RELEASE   .184+02 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .300-09 GRAMS PER CC
MAXIMUM PERMISSIBLE                                    .950-07      .180+04

 CURRENT     DOWN   RADIUS     TIME     VOLUME     CONCENTRATION AVE.SPEC.
VELOCITY  CURRENT                                    ISO-    AVE.   ACTIVITY
  NM/DAY       NM       NM     DAYS         CC    UCI/CC  UCI/CC     UCI/GM
     .50     1.00      .05     2.00   .164+13  .112-05 .119-05   .396+04
     .50     1.00      .10     2.00   .657+13  .767-06 .994-06   .331+04
     .50     1.00      .20     2.00   .263+14  .171-06 .546-06   .182+04
     .50     8.00      .40    16.00   .105+15  .854-08 .908-08   .303+02
     .50     8.00      .80    16.00   .420+15  .587-08 .760-08   .253+02
     .50     8.00     1.60    16.00   .168+16  .131-08 .419-08   .139+02
     .50    40.00     2.00    80.00   .263+16  .118-10 .139-10   .463-01
     .50    40.00     4.00    80.00   .105+17  .898-11 .116-10   .388-01
     .50    40.00     8.00    80.00   .420+17  .200-11 .639-11   .213-01
    4.00     1.00      .05      .25   .164+13  .122-05 .130-05   .433+04
    4.00     1.00      .10      .25   .657+13  .839-06 .109-05   .362+04
    4.00     1.00      .20      .25   .263+14  .187-06 .597-06   .199+04
    4.00     8.00      .40     2.00   .105+15  .174-07 .185-07   .619+02
    4.00     8.00      .80     2.00   .420+15  .120-07 .155-07   .519+02
    4.00     8.00     1.60     2.00   .168+16  .267-08 .853-08   .284+02
    4.00    40.00     2.00    10.00   .263+16  .464-09 .493-09   .164+01
    4.00    40.00     4.00    10.00   .105+17  .319-09 .413-09   .138+01
    4.00    40.00     8.00    10.00   .420+17  .711-10 .227-09   .756+00
   24.00     1.00      .05      .04   .164+13  .123-05 .131-05   .437+04
   24.00     1.00      .10      .04   .657+13  .847-06 .110-05   .366+04
   24.00     1.00      .20      .04   .263+14  .189-06 .603-06   .201+04
   24.00     8.00      .40      .33   .105+15  .190-07 .202-07   .673+02
   24.00     8.00      .80      .33   .420+15  .130-07 .169-07   .563+02
   24.00     8.00     1.60      .33   .168+16  .291-08 .929-08   .310+02
   24.00    40.00     2.00     1.67   .263+16  .709-09 .755-09   .252+01
   24.00    40.00     4.00     1.67   .105+17  .488-09 .632-09   .211+01
   24.00    40.00     8.00     1.67   .420+17  .109-09 .347-09   .116+01
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Down-current Distribution for LOSS-OF-COOLANT Accident, Batch Release

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RADIONUCLIDE   CE 144
HALF LIFE   .284+03 DAYS
TOTAL RELEASE  .140+02 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .300-09 GRAMS PER CC
MAXIMUM PERMISSIBLE                                    .190-06     .230+02

 CURRENT     DOWN  RADIUS     TIME    VOLUME    CONCENTRATION AVE.SPEC.
VELOCITY  CURRENT                                  ISO-    AVE.  ACTIVITY
  NM/DAY       NM      NM     DAYS        CC    UCI/CC  UCI/CC    UCI/GM
     .50     1.00     .05     2.00   .164+13   .936-06 .995-06   .332+04
     .50     1.00     .10     2.00   .657+13   .643-06 .833-06   .278+04
     .50     1.00     .20     2.00   .263+14   .143-06 .458-06   .153+04
     .50     8.00     .40    16.00   .105+15   .141-07 .150-07   .501+02
     .50     8.00     .80    16.00   .420+15   .971-08 .126-07   .419+02
     .50     8.00    1.60    16.00   .168+16   .217-08 .691-08   .230+02
     .50    40.00    2.00    80.00   .263+16   .483-09 .514-09   .171+01
     .50    40.00    4.00    80.00   .105+17   .332-09 .431-09   .144+01
     .50    40.00    8.00    80.00   .420+17   .741-10 .237-09   .788+00
    4.00     1.00     .05      .25   .164+13   .940-06 .100-05   .333+04
    4.00     1.00     .10      .25   .657+13   .646-06 .837-06   .279+04
    4.00     1.00     .20      .25   .263+14   .144-06 .460-06   .153+04
    4.00     8.00     .40     2.00   .105+15   .146-07 .156-07   .518+02
    4.00     8.00     .80     2.00   .420+15   .100-07 .130-07   .434+02
    4.00     8.00    1.60     2.00   .168+16   .224-08 .715-08   .239+02
    4.00    40.00    2.00    10.00   .263+16   .573-09 .610-09   .203+01
    4.00    40.00    4.00    10.00   .105+17   .394-09 .511-09   .170+01
    4.00    40.00    8.00    10.00   .420+17   .879-10 .281-09   .935+00
   24.00     1.00     .05      .04   .164+13   .940-06 .100-05   .333+04
   24.00     1.00     .10      .04   .657+13   .646-06 .837-06   .279+04
   24.00     1.00     .20      .04   .263+14   .144-06 .460-06   .153+04
   24.00     8.00     .40      .33   .105+15   .147-07 .156-07   .521+02
   24.00     8.00     .80      .33   .420+15   .101-07 .131-07   .436+02
   24.00     8.00    1.60      .33   .168+16   .225-08 .718-08   .239+02
   24.00    40.00    2.00     1.67   .263+16   .585-09 .623-09   .209+01
   24.00    40.00    4.00     1.67   .105+17   .402-09 .521-09   .174+01
   24.00    40.00    8.00     1.67   .420+17   .898-10 .286-09   .954+00
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Down-current Distribution, BREACH-OF-CONTAINMENT Accident, Batch Release

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RADIONUCLIDE    H 3
HALF LIFE    .447+04 DAYS
TOTAL RELEASE  .181+03 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .108+00 GRAMS PER CC
MAXIMUM PERMISSIBLE                                  .470-01      .140-02

 CURRENT     DOWN   RADIUS      TIME    VOLUME    CONCENTRATION AVE.SPEC.
VELOCITY  CURRENT                                    ISO-    AVE.  ACTIVITY
  NM/DAY       NM       NM      DAYS         CC   UCI/CC  UCI/CC    UCI/GM
     .50     1.00      .05      2.00   .164+13  .122-04 .129-04   .120-03
     .50     1.00      .10      2.00   .657+13  .835-05 .108-04   .100-03
     .50     1.00      .20      2.00   .263+14  .186-05 .595-05   .550-04
     .50     8.00      .40     16.00   .105+15  .189-06 .202-06   .187-05
     .50     8.00      .80     16.00   .420+15  .130-06 .169-06   .156-05
     .50     8.00     1.60     16.00   .168+16  .271-07 .927-07   .858-06
     .50    40.00     2.00     80.00   .263+16  .750-08 .798-08   .739-07
     .50    40.00     4.00     80.00   .105+17  .516-08 .668-08   .619-07
     .50    40.00     8.00     80.00   .420+17  .115-08 .367-08   .340-07
    4.00     1.00      .05       .25   .164+13  .122-04 .129-04   .120-03
    4.00     1.00      .10       .25   .657+13  .835-05 .108-04   .100-03
    4.00     1.00      .20       .25   .263+14  .186-05 .595-05   .551-04
    4.00     8.00      .40      2.00   .105+15  .190-06 .202-06   .187-05
    4.00     8.00      .80      2.00   .420+15  .130-06 .169-06   .157-05
    4.00     8.00     1.60      2.00   .168+16  .291-07 .929-07   .860-06
    4.00    40.00     2.00     10.00   .263+16  .759-08 .807-08   .747-07
    4.00    40.00     4.00     10.00   .105+17  .521-08 .676-08   .625-07
    4.00    40.00     8.00     10.00   .420+17  .116-08 .371-08   .344-07
   24.00     1.00      .05       .04   .164+13  .122-04 .129-04   .120-03
   24.00     1.00      .10       .04   .657+13  .835-05 .108-04   .100-03
   24.00     1.00      .20       .04   .263+14  .186-05 .595-05   .551-04
   24.00     8.00      .40       .33   .105+15  .190-06 .202-06   .187-05
   24.00     8.00      .80       .33   .420+15  .131-06 .169-06   .157-05
   24.00     8.00     1.60       .33   .168+16  .291-07 .929-07   .860-06
   24.00    40.00     2.00      1.67   .263+16  .760-08 .808-08   .748-07
   24.00    40.00     4.00      1.67   .105+17  .522-08 .676-08   .626-07
   24.00    40.00     8.00      1.67   .420+17  .116-08 .372-08   .344-07
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RADIONUCLIDE   CR 51
HALF LIFE    .278+02 DAYS
TOTAL RELEASE  .129+01 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .500-10 GRAMS PER CC
MAXIMUM PERMISSIBLE                                  .500-06      .310+06

 CURRENT     DOWN   RADIUS      TIME    VOLUME    CONCENTRATION AVE.SPEC.
VELOCITY  CURRENT                                    ISO-    AVE.  ACTIVITY
  NM/DAY       NM       NM      DAYS         CC   UCI/CC  UCI/CC    UCI/GM
     .50     1.00      .05      2.00   .164+13  .824-07 .877-07   .175+04
     .50     1.00      .10      2.00   .657+13  .566-07 .734-07   .147+04
     .50     1.00      .20      2.00   .263+14  .126-07 .403-07   .806+03
     .50     8.00      .40     16.00   .105+15  .908-09 .966-09   .193+02
     .50     8.00      .80     16.00   .420+15  .624-09 .809-09   .162+02
     .50     8.00     1.60     16.00   .168+16  .139-09 .444-09   .889+01
     .50    40.00     2.00     80.00   .263+16  .737-11 .784-11   .157+00
     .50    40.00     4.00     80.00   .105+17  .507-11 .656-11   .131+00
     .50    40.00     8.00     80.00   .420+17  .113-11 .361-11   .721-01
    4.00     1.00      .05       .25   .164+13  .861-07 .916-07   .183+04
    4.00     1.00      .10       .25   .657+13  .592-07 .767-07   .153+04
    4.00     1.00      .20       .25   .263+14  .132-07 .421-07   .842+03
    4.00     8.00      .40      2.00   .105+15  .129-08 .137-08   .274+02
    4.00     8.00      .80      2.00   .420+15  .885-09 .115-08   .229+02
    4.00     8.00     1.60      2.00   .168+16  .197-09 .630-09   .126+02
    4.00    40.00     2.00     10.00   .263+16  .422-10 .449-10   .898+00
    4.00    40.00     4.00     10.00   .105+17  .290-10 .376-10   .752+00
    4.00    40.00     8.00     10.00   .420+17  .647-11 .206-10   .413+00
   24.00     1.00      .05       .04   .164+13  .865-07 .921-07   .184+04
   24.00     1.00      .10       .04   .657+13  .595-07 .771-07   .154+04
   24.00     1.00      .20       .04   .263+14  .133-07 .423-07   .847+03
   24.00     8.00      .40       .33   .105+15  .134-08 .143-08   .286+02
   24.00     8.00      .80       .33   .420+15  .923-09 .120-08   .239+02
   24.00     8.00     1.60       .33   .168+16  .206-09 .657-09   .131+02
   24.00    40.00     2.00      1.67   .263+16  .519-10 .553-10   .111+01
   24.00    40.00     4.00      1.67   .105+17  .357-10 .463-10   .925+00
   24.00    40.00     8.00      1.67   .420+17  .797-11 .254-10   .508+00
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Down-current Distribution, BREACH-OF-CONTAINMENT Accident, Batch Release

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RADIONUCLIDE    MN 54
HALF LIFE    .303+03 DAYS
TOTAL RELEASE  .930-02 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .200-08 GRAMS PER CC
MAXIMUM PERMISSIBLE                                   .380-09      .580+03

 CURRENT     DOWN   RADIUS     TIME    VOLUME    CONCENTRATION AVE.SPEC.
VELOCITY  CURRENT                                  ISO-     AVE.  ACTIVITY
  NM/DAY       NM       NM     DAYS         CC   UCI/CC   UCI/CC    UCI/GM
     .50     1.00      .05     2.00   .164+13  .622-09  .661-09   .331+00
     .50     1.00      .10     2.00   .657+13  .427-09  .554-09   .277+00
     .50     1.00      .20     2.00   .263+14  .953-10  .304-09   .152+00
     .50     8.00      .40    16.00   .105+15  .991-11  .100-10   .500-02
     .50     8.00      .80    16.00   .420+15  .647-11  .838-11   .419-02
     .50     8.00     1.60    16.00   .168+16  .144-11  .460-11   .230-02
     .50    40.00     2.00    80.00   .263+16  .325-12  .346-12   .173-03
     .50    40.00     4.00    80.00   .105+17  .223-12  .290-12   .145-03
     .50    40.00     8.00    80.00   .420+17  .499-13  .159-12   .795-04
    4.00     1.00      .05      .25   .164+13  .624-09  .664-09   .332+00
    4.00     1.00      .10      .25   .657+13  .429-09  .556-09   .278+00
    4.00     1.00      .20      .25   .263+14  .957-10  .305-09   .153+00
    4.00     8.00      .40     2.00   .105+15  .971-11  .103-10   .517-02
    4.00     8.00      .80     2.00   .420+15  .564-11  .865-11   .433-02
    4.00     8.00     1.60     2.00   .168+16  .149-11  .475-11   .238-02
    4.00    40.00     2.00    10.00   .263+16  .382-12  .406-12   .203-03
    4.00    40.00     4.00    10.00   .105+17  .262-12  .340-12   .170-03
    4.00    40.00     8.00    10.00   .420+17  .585-13  .187-12   .933-04
   24.00     1.00      .05      .04   .164+13  .625-09  .664-09   .332+00
   24.00     1.00      .10      .04   .657+13  .429-09  .556-09   .278+00
   24.00     1.00      .20      .04   .263+14  .958-10  .306-09   .153+00
   24.00     8.00      .40      .33   .105+15  .976-11  .104-10   .519-02
   24.00     8.00      .80      .33   .420+15  .670-11  .868-11   .434-02
   24.00     8.00     1.60      .33   .168+16  .150-11  .477-11   .239-02
   24.00    40.00     2.00     1.67   .263+16  .389-12  .414-12   .207-03
   24.00    40.00     4.00     1.67   .105+17  .267-12  .346-12   .173-03
   24.00    40.00     8.00     1.67   .420+17  .596-13  .190-12   .951-04
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RADIONUCLIDE    FE 55
HALF LIFE    .949+03 DAYS
TOTAL RELEASE  .450-01 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .100-07 GRAMS PER CC
MAXIMUM PERMISSIBLE                                   .250-07      .390+01

 CURRENT     DOWN   RADIUS     TIME    VOLUME    CONCENTRATION AVE.SPEC.
VELOCITY  CURRENT                                  ISO-     AVE.  ACTIVITY
  NM/DAY       NM       NM     DAYS         CC   UCI/CC   UCI/CC    UCI/GM
     .50     1.00      .05     2.00   .164+13  .302-08  .321-08   .321+00
      50     1.00      .10     2.00   .657+13  .207-08  .269-08   .269+00
     .50     1.00      .20     2.00   .263+14  .463-09  .148-08   .148+00
     .50     8.00      .40    16.00   .105+15  .467-10  .496-10   .496-02
     .50     8.00      .80    16.00   .420+15  .371-10  .416-10   .416-02
     .50     8.00     1.60    16.00   .168+16  .716-11  .228-10   .228-02
     .50    40.00     2.00    80.00   .263+16  .178-11  .190-11   .190-03
     .50    40.00     4.00    80.00   .105+17  .122-11  .159-11   .159-03
     .50    40.00     8.00    80.00   .420+17  .273-12  .872-12   .872-04
    4.00     1.00      .05      .25   .164+13  .302-08  .321-08   .321+00
    4.00     1.00      .10      .25   .657+13  .208-08  .269-08   .269+00
    4.00     1.00      .20      .25   .263+14  .463-09  .148-08   .148+00
    4.00     8.00      .40     2.00   .105+15  .472-10  .502-10   .502-02
    4.00     8.00      .80     2.00   .420+15  .324-10  .420-10   .420-02
    4.00     8.00     1.60     2.00   .168+16  .723-11  .231-10   .231-02
    4.00    40.00     2.00    10.00   .263+16  .198-11  .199-11   .199-03
    4.00    40.00     4.00    10.00   .105+17  .129-11  .167-11   .167-03
    4.00    40.00     8.00    10.00   .420+17  .288-12  .917-12   .917-04
   24.00     1.00      .05      .04   .164+13  .302-08  .321-08   .321+00
   24.00     1.00      .10      .04   .657+13  .208-08  .269-08   .269+00
   24.00     1.00      .20      .04   .263+14  .463-09  .148-08   .148+00
   24.00     8.00      .40      .33   .105+15  .472-10  .502-10   .502-02
   24.00     8.00      .80      .33   .420+15  .324-10  .420-10   .420-02
   24.00     8.00     1.60      .33   .168+16  .724-11  .231-10   .231-02
   24.00    40.00     2.00     1.67   .263+16  .194-11  .201-11   .201-03
   24.00    40.00     4.00     1.67   .105+17  .130-11  .168-11   .168-03
   24.00    40.00     8.00     1.67   .420+17  .289-12  .923-12   .923-04
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Down-current Distribution, BREACH-OF-CONTAINMENT Accident, Batch Release

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RADIONUCLIDE   CO 58
HALF LIFE   .713+02 DAYS
TOTAL RELEASE  .158+01 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .500-09 GRAMS PER CC
MAXIMUM PERMISSIBLE                                 .230-07     .890+02

 CURRENT    DOWN  RADIUS     TIME    VOLUME    CONCENTRATION AVE.SPEC.
VELOCITY CURRENT                                  ISO-    AVE.  ACTIVITY
  NM/DAY      NM      NM     DAYS        CC    UCI/CC  UCI/CC    UCI/GM
     .50    1.00     .05     2.00   .164+13   .104-06 .111-06   .221+03
     .50    1.00     .10     2.00   .657+13   .715-07 .927-07   .185+03
     .50    1.00     .20     2.00   .263+14   .162-07 .509-07   .102+03
     .50    8.00     .40    16.00   .105+15   .142-08 .151-08   .302+01
     .50    8.00     .80    16.00   .420+15   .975-09 .126-08   .253+01
     .50    8.00    1.60    16.00   .168+16   .218-09 .694-09   .139+01
     .50   40.00    2.00    80.00   .263+16   .305-10 .324-10   .648-01
     .50   40.00    4.00    80.00   .105+17   .209-10 .271-10   .543-01
     .50   40.00    8.00    80.00   .420+17   .467-11 .149-10   .298-01
    4.00    1.00     .05      .25   .164+13   .106-06 .113-06   .225+03
    4.00    1.00     .10      .25   .657+13   .724-07 .943-07   .189+03
    4.00    1.00     .20      .25   .263+14   .162-07 .518-07   .104+03
    4.00    8.00     .40     2.00   .105+15   .163-08 .173-08   .346+01
    4.00    8.00     .80     2.00   .420+15   .112-08 .145-08   .290+01
    4.00    8.00    1.60     2.00   .168+16   .249-09 .796-09   .159+01
    4.00   40.00    2.00    10.00   .263+16   .507-10 .640-10   .128+00
    4.00   40.00    4.00    10.00   .105+17   .414-10 .536-10   .107+00
    4.00   40.00    8.00    10.00   .420+17   .923-11 .294-10   .589-01
   24.00    1.00     .05      .04   .164+13   .106-06 .113-06   .226+03
   24.00    1.00     .10      .04   .657+13   .729-07 .945-07   .189+03
   24.00    1.00     .20      .04   .263+14   .163-07 .519-07   .104+03
   24.00    8.00     .40      .33   .105+15   .165-08 .176-08   .352+01
   24.00    8.00     .80      .33   .420+15   .114-08 .147-08   .294+01
   24.00    8.00    1.60      .33   .168+16   .253-09 .809-09   .162+01
   24.00   40.00    2.00     1.67   .263+16   .653-10 .694-10   .139+00
   24.00   40.00    4.00     1.67   .105+17   .448-10 .581-10   .116+00
   24.00   40.00    8.00     1.67   .420+17   .190-10 .319-10   .639-01
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RADIONUCLIDE   FE 59
HALF LIFE   .456+02 DAYS
TOTAL RELEASE  .720-02 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .100-07 GRAMS PER CC
MAXIMUM PERMISSIBLE                                 .470-08     .890+00

 CURRENT    DOWN  RADIUS     TIME    VOLUME    CONCENTRATION AVE.SPEC.
VELOCITY CURRENT                                  ISO-    AVE.  ACTIVITY
  NM/DAY      NM      NM     DAYS        CC    UCI/CC  UCI/CC    UCI/GM
     .50    1.00     .05     2.00   .164+13   .469-09 .499-09   .499-01
     .50    1.00     .10     2.00   .657+13   .322-09 .418-09   .418-01
     .50    1.00     .20     2.00   .263+14   .719-10 .229-09   .229-01
     .50    8.00     .40    16.00   .105+15   .592-11 .630-11   .630-03
     .50    8.00     .80    16.00   .420+15   .407-11 .528-11   .528-03
     .50    8.00    1.60    16.00   .168+16   .909-12 .290-11   .290-03
     .50   40.00    2.00    80.00   .263+16   .896-13 .953-13   .953-05
     .50   40.00    4.00    80.00   .105+17   .616+13 .798-13   .798-05
     .50   40.00    8.00    80.00   .420+17   .137-13 .438-13   .438-05
    4.00    1.00     .05      .25   .164+13   .482-09 .512-09   .512-01
    4.00    1.00     .10      .25   .657+13   .331-09 .429-09   .429-01
    4.00    1.00     .20      .25   .263+14   .739-10 .236-09   .236-01
    4.00    8.00     .40     2.00   .105+15   .733-11 .780-11   .780-03
    4.00    8.00     .80     2.00   .420+15   .504-11 .653-11   .653-03
    4.00    8.00    1.60     2.00   .168+16   .112-11 .359-11   .359-03
    4.00   40.00    2.00    10.00   .263+16   .260-12 .276-12   .276-04
    4.00   40.00    4.00    10.00   .105+17   .178-12 .231-12   .231-04
    4.00   40.00    8.00    10.00   .420+17   .398-13 .127-12   .127-04
   24.00    1.00     .05      .04   .164+13   .483-09 .514-09   .514-01
   24.00    1.00     .10      .04   .657+13   .332-09 .430-09   .430-01
   24.00    1.00     .20      .04   .263+14   .741-10 .236-09   .236-01
   24.00    8.00     .40      .33   .105+15   .752-11 .800-11   .800-03
   24.00    8.00     .80      .33   .420+15   .517-11 .669-11   .669-03
   24.00    8.00    1.60      .33   .168+16   .115-11 .368-11   .368-03
   24.00   40.00    2.00     1.67   .263+16   .295-12 .313-12   .313-04
   24.00   40.00    4.00     1.67   .105+17   .203-12 .262-12   .262-04
   24.00   40.00    8.00     1.67   .420+17   .452-13 .144-12   .144-04
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Down-current Distribution, BREACH-OF-CONTAINMENT Accident, Batch Release

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RADIONUCLIDE   CO 60
HALF LIFE   .192+04 DAYS
TOTAL RELEASE   .176+00 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .500-08 GRAMS PER CC
MAXIMUM PERMISSIBLE
                                                 .150-07      .330+02

 CURRENT     DOWN   RADIUS     TIME    VOLUME    CONCENTRATION AVE.SPEC.
VELOCITY CURRENT                                    ISO-    AVE.  ACTIVITY
  NM/DAY      NM       NM     DAYS          CC   UCI/CC  UCI/CC.    UCI/GM
     .50    1.00      .05     2.00   .164+13  .118-07 .126-07   .251+02
     .50    1.00      .10     2.00   .657+13  .812-08 .105-07   .210+02
     .50    1.00      .20     2.00   .263+14  .181-08 .578-08   .116+02
     .50    8.00      .40    16.00   .105+15  .184-09 .195-09   .391+00
     .50    8.00      .80    16.00   .420+15  .126-09 .164-09   .327+00
     .50    8.00     1.60    16.00   .168+16  .282-10 .898-10   .180+00
     .50   40.00     2.00    80.00   .263+16  .718-11 .764-11   .153-01
     .50   40.00     4.00    80.00   .105+17  .493-11 .639-11   .128-01
     .50   40.00     8.00    80.00   .420+17  .112-11 .351-11   .702-02
    4.00    1.00      .05      .25   .164+13  .118-07 .126-07   .251+02
    4.00    1.00      .10      .25   .657+13  .812-08 .105-07   .211+02
    4.00    1.00      .20      .25   .263+14  .181-08 .578-08   .116+02
    4.00    8.00      .40     2.00   .105+15  .185-09 .196-09   .393+00
    4.00    8.00      .80     2.00   .420+15  .127-09 .164-09   .329+00
    4.00    8.00     1.60     2.00   .168+16  .283-10 .903-10   .181+00
    4.00   40.00     2.00    10.00   .263+16  .736-11 .783-11   .157-01
    4.00   40.00     4.00    10.00   .105+17  .506-11 .656-11   .131-01
    4.00   40.00     8.00    10.00   .420+17  .113-11 .360-11   .720-02
   24.00    1.00      .05      .04   .164+13  .118-07 .126-07   .251+02
   24.00    1.00      .10      .04   .657+13  .812-08 .105-07   .211+02
   24.00    1.00      .20      .04   .263+14  .181-08 .578-08   .116+02
   24.00    8.00      .40      .33   .105+15  .185-09 .196-09   .393+00
   24.00    8.00      .80      .33   .420+15  .127-09 .164-09   .329+00
   24.00    8.00     1.60      .33   .168+16  .283-10 .903-10   .181+00
   24.00   40.00     2.00     1.67   .263+16  .738-11 .785-11   .157-01
   24.00   40.00     4.00     1.67   .105+17  .507-11 .657-11   .131-01
   24.00   40.00     8.00     1.67   .420+17  .113-11 .361-11   .722-02
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RADIONUCLIDE   GE 78
HALF LIFE   .613-01 DAYS
TOTAL RELEASE   .597-03 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .700-10 GRAMS PER CC
MAXIMUM PERMISSIBLE
                                                 .000         .000

 CURRENT     DOWN   RADIUS     TIME    VOLUME    CONCENTRATION AVE.SPEC.
VELOCITY CURRENT                                    ISO-    AVE.  ACTIVITY
  NM/DAY      NM       NM     DAYS          CC   UCI/CC  UCI/CC     UCI/GM
     .50    1.00      .05     2.00   .164+13  .608-20 .696-20   .923-10
     .50    1.00      .10     2.00   .657+13  .418-20 .541-20   .773-10
     .50    1.00      .20     2.00   .263+14  .932-21 .297-20   .425-10
     .50    8.00      .40    16.00   .105+15  .000    .000      .000
     .50    8.00      .80    16.00   .420+15  .000    .000      .000
     .50    8.00     1.60    16.00   .168+16  .000    .000      .000
     .50   40.00     2.00    80.00   .263+16  .000    .000      .000
     .50   40.00     4.00    80.00   .105+17  .000    .000      .000
     .50   40.00     8.00    80.00   .420+17  .000    .000      .000
    4.00    1.00      .05      .25   .164+13  .237-11 .253-11   .361-01
    4.00    1.00      .10      .25   .657+13  .163-11 .211-11   .302-01
    4.00    1.00      .20      .25   .263+14  .369-12 .116-11   .166-01
    4.00    8.00      .40     2.00   .105+15  .949-22 .101-21   .144-11
    4.00    8.00      .80     2.00   .420+15  .653-22 .846-22   .121-11
    4.00    8.00     1.60     2.00   .168+16  .146-22 .464-22   .664-12
    4.00   40.00     2.00    10.00   .263+16  .000    .000      .000
    4.00   40.00     4.00    10.00   .105+17  .000    .000      .000
    4.00   40.00     8.00    10.00   .420+17  .000    .000      .000
   24.00    1.00      .05      .04   .164+13  .250-10 .266-10   .380+00
   24.00    1.00      .10      .04   .657+13  .172-10 .223-10   .318+00
   24.00    1.00      .20      .04   .263+14  .399-11 .122-10   .175+00
   24.00    8.00      .40      .33   .105+15  .145-13 .154-13   .220-03
   24.00    8.00      .80      .33   .420+15  .994-14 .129-13   .184-03
   24.00    8.00     1.60      .33   .168+16  .222-14 .708-14   .101-03
   24.00   40.00     2.00     1.67   .263+16  .164-21 .175-21   .250-11
   24.00   40.00     4.00     1.67   .105+17  .113-21 .146-21   .209-11
   24.00   40.00     8.00     1.67   .420+17  .252-22 .805-22   .115-11
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Down-current Distribution, BREACH-OF-CONTAINMENT Accident, Batch Release

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RADIONUCLIDE   AS 78
HALF LIFE   .632-01 DAYS
TOTAL RELEASE  .117-02 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .300-08 GRAMS PER CC
MAXIMUM PERMISSIBLE                                   .000         .000
DAUGHTER OF PREVIOUS RADIONUCLIDE, DECAY FRACTION =  1.0000

 CURRENT    DOWN  RADIUS     TIME    VOLUME    CONCENTRATION AVE.SPEC.
VELOCITY CURRENT                                 ISO-   AVE.  ACTIVITY
  NM/DAY      NM      NM     DAYS        CC   UCI/CC  UCI/CC    UCI/GM
     .50    1.00     .05     2.00  .164+13  .214-18 .229-18   .760-10
     .50    1.00     .10     2.00  .657+13  .147-18 .191-18   .636-10
     .50    1.00     .20     2.00  .263+14  .329-19 .105-18   .350-10
     .50    8.00     .40    16.00  .105+15  .000    .000      .000
     .50    8.00     .80    16.00  .420+15  .000    .000      .000
     .50    8.00    1.60    16.00  .168+16  .000    .000      .000
     .50   40.00    2.00    80.00  .263+16  .000    .000      .000
     .50   40.00    4.00    80.00  .105+17  .000    .000      .000
     .50   40.00    8.00    80.00  .420+17  .000    .000      .000
    4.00    1.00     .05      .25  .164+13  .119-10 .126-10   .421-02
    4.00    1.00     .10      .25  .657+13  .815-11 .106-10   .352-02
    4.00    1.00     .20      .25  .263+14  .192-11 .590-11   .193-02
    4.00    8.00     .40     2.00  .105+15  .335-20 .356-20   .119-11
    4.00    8.00     .80     2.00  .420+15  .239-20 .298-20   .994-12
    4.00    8.00    1.60     2.00  .168+16  .519-21 .164-20   .596-12
    4.00   40.00    2.00    10.00  .263+16  .000    .000      .000
    4.00   40.00    4.00    10.00  .105+17  .000    .000      .000
    4.00   40.00    8.00    10.00  .420+17  .000    .000      .000
   24.00    1.00     .05      .04  .164+13  .613-10 .652-10   .217-01
   24.00    1.00     .10      .04  .657+13  .421-10 .546-10   .182-01
   24.00    1.00     .20      .04  .263+14  .940-11 .300-10   .999-02
   24.00    8.00     .40      .33  .105+15  .877-13 .933-13   .311-09
   24.00    8.00     .80      .33  .420+15  .603-13 .781-13   .260-09
   24.00    8.00    1.60      .33  .168+16  .135-13 .429-13   .143-09
   24.00   40.00    2.00     1.67  .263+16  .461-20 .491-20   .164-11
   24.00   40.00    4.00     1.67  .105+17  .317-20 .411-20   .137-11
   24.00   40.00    8.00     1.67  .420+17  .707-21 .226-20   .752-12


RADIONUCLIDE   BR 84
HALF LIFE   .221-01 DAYS
TOTAL RELEASE  .182+02 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .650-04 GRAMS PER CC
MAXIMUM PERMISSIBLE                                   .000         .000

 CURRENT    DOWN  RADIUS     TIME    VOLUME    CONCENTRATION AVE.SPEC.
VELOCITY CURRENT                                 ISO-   AVE.  ACTIVITY
  NM/DAY      NM      NM     DAYS        CC   UCI/CC  UCI/CC    UCI/GM
     .50    1.00     .05     2.00  .164+13  .709-33 .754-33   .116-28
     .50    1.00     .10     2.00  .657+13  .487-33 .631-33   .971-29
     .50    1.00     .20     2.00  .263+14  .199-33 .347-33   .533-29
     .50    8.00     .40    16.00  .105+15  .000    .000      .000
     .50    8.00     .80    16.00  .420+15  .000    .000      .000
     .50    8.00    1.60    16.00  .168+16  .000    .000      .000
     .50   40.00    2.00    80.00  .263+16  .000    .000      .000
     .50   40.00    4.00    80.00  .105+17  .000    .000      .000
     .50   40.00    8.00    80.00  .420+17  .000    .000      .000
    4.00    1.00     .05      .25  .164+13  .481-09 .512-09   .788-05
    4.00    1.00     .10      .25  .657+13  .331-09 .429-09   .660-05
    4.00    1.00     .20      .25  .263+14  .738-10 .236-09   .362-05
    4.00    8.00     .40     2.00  .105+15  .111-34 .118-34   .181-30
    4.00    8.00     .80     2.00  .420+15  .761-35 .986-35   .152-30
    4.00    8.00    1.60     2.00  .168+16  .170-35 .542-35   .833-31
    4.00   40.00    2.00    10.00  .263+16  .000    .000      .000
    4.00   40.00    4.00    10.00  .105+17  .000    .000      .000
    4.00   40.00    8.00    10.00  .420+17  .000    .000      .000
   24.00    1.00     .05      .04  .164+13  .331-06 .352-06   .542-02
   24.00    1.00     .10      .04  .657+13  .227-06 .295-06   .453-02
   24.00    1.00     .20      .04  .263+14  .507-07 .162-06   .249-02
   24.00    8.00     .40      .33  .105+15  .551-12 .587-12   .903-08
   24.00    8.00     .80      .33  .420+15  .379-12 .491-12   .756-08
   24.00    8.00    1.60      .33  .168+16  .846-13 .270-12   .415-08
   24.00   40.00    2.00     1.67  .263+16  .153-31 .163-31   .251-27
   24.00   40.00    4.00     1.67  .105+17  .105-31 .137-31   .210-27
   24.00   40.00    8.00     1.67  .420+17  .235-32 .750-32   .115-27
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Down-current Distribution, BREACH-OF-CONTAINMENT Accident, Batch Release

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RADIONUCLIDE   KR 85M
HALF LIFE    .183+00 DAYS
TOTAL RELEASE   .854+06 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .300-09 GRAMS PER CC
MAXIMUM PERMISSIBLE                                .000         .000

 CURRENT     DOWN  RADIUS     TIME     VOLUME    CONCENTRATION AVE.SPEC.
VELOCITY CURRENT                                   ISO-    AVE.  ACTIVITY
  NM/DAY      NM      NM      DAYS         CC   UCI/CC  UCI/CC    UCI/GM
     .50    1.00     .05      2.00   .164+13  .296-04 .315-04   .105+06
     .50    1.00     .10      2.00   .657+13  .209-04 .264-04   .880+05
     .50    1.00     .20      2.00   .263+14  .955-05 .145-04   .483+05
     .50    8.00     .40     16.00   .105+15  .437-29 .465-29   .155-19
     .50    8.00     .80     16.00   .420+15  .301-29 .390-29   .130-19
     .50    8.00    1.60     16.00   .168+16  .671-30 .219-29   .713-20
     .50   40.00    2.00     80.00   .263+16  .000    .000      .000
     .50   40.00    4.00     80.00   .105+17  .000    .000      .000
     .50   40.00    8.00     80.00   .420+17  .000    .000      .000
    4.00    1.00     .05       .25   .164+13  .224-01 .238-01   .794+08
    4.00    1.00     .10       .25   .657+13  .154-01 .199-01   .664+08
    4.00    1.00     .20       .25   .263+14  .343-02 .110-01   .365+08
    4.00    8.00     .40      2.00   .105+15  .463-06 .493-06   .164+04
    4.00    8.00     .80      2.00   .420+15  .318-06 .412-06   .137+04
    4.00    8.00    1.60      2.00   .168+16  .710-07 .227-06   .755+03
    4.00   40.00    2.00     10.00   .263+16  .179-20 .137-20   .458-11
    4.00   40.00    4.00     10.00   .105+17  .887-21 .115-20   .383-11
    4.00   40.00    8.00     10.00   .420+17  .198-21 .631-21   .210-11
   24.00    1.00     .05       .04   .164+13  .493-01 .524-01   .175+09
   24.00    1.00     .10       .04   .657+13  .339-01 .439-01   .146+09
   24.00    1.00     .20       .04   .263+14  .756-02 .241-01   .803+08
   24.00    8.00     .40       .33   .105+15  .255-03 .271-03   .905+06
   24.00    8.00     .80       .33   .420+15  .175-03 .227-03   .757+06
   24.00    8.00    1.60       .33   .168+16  .391-04 .125-03   .416+06
   24.00   40.00    2.00      1.67   .263+16  .655-07 .696-07   .232+03
   24.00   40.00    4.00      1.67   .105+17  .450-07 .583-07   .194+03
   24.00   40.00    8.00      1.67   .420+17  .100-07 .320-07   .107+03
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RADIONUCLIDE   KR 85
HALF LIFE   .393+04 DAYS
TOTAL RELEASE  .470+06 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .300-09 GRAMS PER CC
MAXIMUM PERMISSIBLE                                .000         .000
DAUGHTER OF PREVIOUS RADIONUCLIDE, DECAY FRACTION =   .2300

 CURRENT     DOWN  RADIUS     TIME     VOLUME    CONCENTRATION AVE.SPEC.
VELOCITY CURRENT                                   ISO-    AVE.  ACTIVITY
  NM/DAY      NM      NM      DAYS         CC   UCI/CC  UCI/CC    UCI/GM
     .50    1.00     .05      2.00   .164+13  .316-01 .336-01   .112+09
     .50    1.00     .10      2.00   .657+13  .217-01 .281-01   .937+08
     .50    1.00     .20      2.00   .263+14  .484-02 .154-01   .515+08
     .50    8.00     .40     16.00   .105+15  .492-03 .523-03   .174+07
     .50    8.00     .80     16.00   .420+15  .338-03 .439-03   .146+07
     .50    8.00    1.60     16.00   .168+16  .754-04 .241-03   .802+06
     .50   40.00    2.00     80.00   .263+16  .195-04 .207-04   .690+05
     .50   40.00    4.00     80.00   .105+17  .134-04 .173-04   .577+05
     .50   40.00    8.00     80.00   .420+17  .296-05 .952-05   .317+05
    4.00    1.00     .05       .25   .164+13  .316-01 .336-01   .112+09
    4.00    1.00     .10       .25   .657+13  .217-01 .281-01   .937+08
    4.00    1.00     .20       .25   .263+14  .484-02 .154-01   .515+08
    4.00    8.00     .40      2.00   .105+15  .493-03 .524-03   .175+07
    4.00    8.00     .80      2.00   .420+15  .339-03 .439-03   .146+07
    4.00    8.00    1.60      2.00   .168+16  .756-04 .241-03   .804+06
    4.00   40.00    2.00     10.00   .263+16  .197-04 .209-04   .698+05
    4.00   40.00    4.00     10.00   .105+17  .135-04 .175-04   .585+05
    4.00   40.00    8.00     10.00   .420+17  .302-05 .963-05   .321+05
   24.00    1.00     .05       .04   .164+13  .316-01 .336-01   .112+09
   24.00    1.00     .10       .04   .657+13  .217-01 .281-01   .937+08
   24.00    1.00     .20       .04   .263+14  .484-02 .154-01   .515+08
   24.00    8.00     .40       .33   .105+15  .493-03 .525-03   .175+07
   24.00    8.00     .80       .33   .420+15  .339-03 .439-03   .146+07
   24.00    8.00    1.60       .33   .168+16  .756-04 .241-03   .804+06
   24.00   40.00    2.00      1.67   .263+16  .197-04 .210-04   .699+05
   24.00   40.00    4.00      1.67   .105+17  .136-04 .176-04   .585+05
   24.00   40.00    8.00      1.67   .420+17  .302-05 .965-05   .322+05
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Down-current Distribution, BREACH-OF-CONTAINMENT Accident, Batch Release

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RADIONUCLIDE   KR 87
HALF LIFE    .528-01 DAYS
TOTAL RELEASE  .911+06 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .300-09 GRAMS PER CC
MAXIMUM PERMISSIBLE                                   .000        .000

 CURRENT     DOWN  RADIUS      TIME    VOLUME    CONCENTRATION AVE.SPEC.
VELOCITY  CURRENT                                   ISO-    AVE.  ACTIVITY
  NM/DAY       NM      NM      DAYS        CC    UCI/CC  UCI/CC    UCI/GM
     .50     1.00     .05      2.00  .164+13  .243-12 .259-12   .863-03
     .50     1.00     .10      2.00  .657+13  .167-12 .217-12   .723-03
     .50     1.00     .20      2.00  .263+14  .373-13 .119-12   .397-03
     .50     8.00     .40     16.00  .105+15  .000    .000      .000
     .50     8.00     .80     16.00  .420+15  .000    .000      .000
     .50     8.00    1.60     16.00  .168+16  .000    .000      .000
     .50    40.00    2.00     80.00  .263+16  .000    .000      .000
     .50    40.00    4.00     80.00  .105+17  .000    .000      .000
     .50    40.00    8.00     80.00  .420+17  .000    .000      .000
    4.00     1.00     .05       .25  .164+13  .230-02 .245-02   .815+07
    4.00     1.00     .10       .25  .657+13  .158-02 .205-02   .683+07
    4.00     1.00     .20       .25  .263+14  .353-03 .112-02   .375+07
    4.00     8.00     .40      2.00  .105+15  .380-14 .405-14   .135-04
    4.00     8.00     .80      2.00  .420+15  .261-14 .339-14   .113-04
    4.00     8.00    1.60      2.00  .168+16  .523-15 .186-14   .620-05
    4.00    40.00    2.00     10.00  .263+16  .000    .000      .000
    4.00    40.00    4.00     10.00  .105+17  .000    .000      .000
    4.00    40.00    8.00     10.00  .420+17  .000    .000      .000
   24.00     1.00     .05       .04  .164+13  .354-01 .377-01   .126+09
   24.00     1.00     .10       .04  .657+13  .243-01 .315-01   .105+09
   24.00     1.00     .20       .04  .263+14  .543-02 .173-01   .577+08
   24.00     8.00     .40       .33  .105+15  .120-04 .128-04   .427+05
   24.00     8.00     .80       .33  .420+15  .827-05 .107-04   .357+05
   24.00     8.00    1.60       .33  .168+16  .135-05 .589-05   .196+05
   24.00    40.00    2.00      1.67  .263+16  .121-13 .129-13   .429-04
   24.00    40.00    4.00      1.67  .105+17  .831-14 .108-13   .359-04
   24.00    40.00    8.00      1.67  .420+17  .185-14 .591-14   .197-04
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RADIONUCLIDE   KR 88
HALF LIFE    .117+00 DAYS
TOTAL RELEASE  .193+07 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .300-09 GRAMS PER CC
MAXIMUM PERMISSIBLE                                   .000        .000

 CURRENT     DOWN  RADIUS      TIME    VOLUME    CONCENTRATION AVE.SPEC.
VELOCITY  CURRENT                                   ISO-    AVE.  ACTIVITY
  NM/DAY       NM      NM      DAYS        CC    UCI/CC  UCI/CC    UCI/GM
     .50     1.00     .05      2.00  .164+13  .929-06 .988-06   .329+04
     .50     1.00     .10      2.00  .657+13  .634-06 .827-06   .276+04
     .50     1.00     .20      2.00  .263+14  .142-06 .454-06   .151+04
     .50     8.00     .40     16.00  .105+15  .000    .000      .000
     .50     8.00     .80     16.00  .420+15  .000    .000      .000
     .50     8.00    1.60     16.00  .168+16  .000    .000      .000
     .50    40.00    2.00     80.00  .263+16  .000    .000      .000
     .50    40.00    4.00     80.00  .105+17  .000    .000      .000
     .50    40.00    8.00     80.00  .420+17  .000    .000      .000
    4.00     1.00     .05       .25  .164+13  .295-01 .314-01   .105+09
    4.00     1.00     .10       .25  .657+13  .203-01 .263-01   .875+08
    4.00     1.00     .20       .25  .263+14  .452-02 .144-01   .481+08
    4.00     8.00     .40      2.00  .105+15  .145-07 .154-07   .515+02
    4.00     8.00     .80      2.00  .420+15  .997-08 .129-07   .431+02
    4.00     8.00    1.60      2.00  .168+16  .223-08 .710-08   .237+02
    4.00    40.00    2.00     10.00  .263+16  .153-29 .163-29   .543-20
    4.00    40.00    4.00     10.00  .105+17  .105-29 .136-29   .454-20
    4.00    40.00    8.00     10.00  .420+17  .235-30 .749-30   .250-20
   24.00     1.00     .05       .04  .164+13  .101+00 .108+00   .359+09
   24.00     1.00     .10       .04  .657+13  .876-01 .902-01   .301+09
   24.00     1.00     .20       .04  .263+14  .155-01 .495-01   .165+09
   24.00     8.00     .40       .33  .105+15  .281-03 .299-03   .997+06
   24.00     8.00     .80       .33  .420+15  .193-03 .250-03   .835+06
   24.00     8.00    1.60       .33  .168+16  .431-04 .138-03   .459+06
   24.00    40.00    2.00      1.67  .263+16  .418-08 .445-08   .148+02
   24.00    40.00    4.00      1.67  .105+17  .287-08 .372-08   .124+02
   24.00    40.00    8.00      1.67  .420+17  .641-09 .205-08   .682+01
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Down-current Distribution, BREACH-OF-CONTAINMENT Accident, Batch Release

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RADIONUCLIDE   RB 88
HALF LIFE   .124-01 DAYS
TOTAL RELEASE  .100+04 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .120-06 GRAMS PER CC
MAXIMUM PERMISSIBLE                                  .000          .000
DAUGHTER OF PREVIOUS RADIONUCLIDE, DECAY FRACTION =  1.0000

 CURRENT    DOWN   RADIUS     TIME     VOLUME    CONCENTRATION A/E.SPEC.
VELOCITY CURRENT                                    ISO-    AVE.  ACTIVITY
  NM/DAY      KM       KM     DAYS          CC    UCI/CC  UCI/CC    UCI/GM
     .50    1.00      .05     2.00   .164+13  .104-05 .111-05   .971+01
     .50    1.00      .10     2.00   .657+13  .714-06 .925-06   .771+01
     .50    1.00      .20     2.00   .263+14  .159-06 .508-06   .424+01
     .50    8.00      .40    16.00   .105+15  .000    .000      .000
     .50    8.00      .80    16.00   .420+15  .000    .000      .000
     .50    8.00     1.60    16.00   .168+16  .000    .000      .000
     .50   40.00     2.00    80.00   .263+16  .000    .000      .000
     .50   40.00     4.00    80.00   .105+17  .000    .000      .000
     .50   40.00     8.00    80.00   .420+17  .000    .000      .000
    4.00    1.00      .05      .25   .164+13  .330-01 .351-01   .292+06
    4.00    1.00      .10      .25   .657+13  .227-01 .294-01   .245+06
    4.00    1.00      .20      .25   .263+14  .506-02 .161-01   .134+06
    4.00    8.00      .40     2.00   .105+15  .162-07 .173-07   .144+00
    4.00    8.00      .80     2.00   .420+15  .112-07 .145-07   .120+00
    4.00    8.00     1.60     2.00   .168+16  .249-08 .794-08   .662-01
    4.00   40.00     2.00    10.00   .263+16  .171-29 .182-29   .152-22
    4.00   40.00     4.00    10.00   .105+17  .118-29 .152-29   .127-22
    4.00   40.00     8.00    10.00   .420+17  .263-30 .838-30   .698-23
   24.00    1.00      .05      .04   .164+13  .992-01 .105+00   .879+06
   24.00    1.00      .10      .04   .657+13  .691-01 .883-01   .736+06
   24.00    1.00      .20      .04   .263+14  .152-01 .485-01   .404+06
   24.00    8.00      .40      .33   .105+15  .315-03 .335-03   .279+04
   24.00    8.00      .80      .33   .420+15  .214-03 .280-03   .233+04
   24.00    8.00     1.60      .33   .168+16  .482-04 .154-03   .128+04
   24.00   40.00     2.00     1.67   .263+16  .468-08 .497-08   .415-01
   24.00   40.00     4.00     1.67   .105+17  .321-08 .416-08   .347-01
   24.00   40.00     8.00     1.67   .420+17  .717-09 .229-08   .191-01
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RADIONUCLIDE   RB 89
HALF LIFE   .107-01 DAYS
TOTAL RELEASE  .248+02 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .120-06 GRAMS PER CC
MAXIMUM PERMISSIBLE                                  .000          .000

 CURRENT    DOWN   RADIUS     TIME     VOLUME    CONCENTRATION AVE.SPEC.
VELOCITY CURRENT                                    ISO-    AVE.  ACTIVITY
  NM/DAY      KM       KM     DAYS          CC    UCI/CC  UCI/CC    UCI/GM
     .50    1.00      .05     2.00   .164+13  .000    .000      .000
     .50    1.00      .10     2.00   .657+13  .000    .000      .000
     .50    1.00      .20     2.00   .263+14  .000    .000      .000
     .50    8.00      .40    16.00   .105+15  .000    .000      .000
     .50    8.00      .80    16.00   .420+15  .000    .000      .000
     .50    8.00     1.60    16.00   .168+16  .000    .000      .000
     .50   40.00     2.00    80.00   .263+16  .000    .000      .000
     .50   40.00     4.00    80.00   .105+17  .000    .000      .000
     .50   40.00     8.00    80.00   .420+17  .000    .000      .000
    4.00    1.00      .05      .25   .164+13  .155-12 .165-12   .137-05
    4.00    1.00      .10      .25   .657+13  .106-12 .138-12   .115-05
    4.00    1.00      .20      .25   .263+14  .237-13 .757-13   .631-06
    4.00    8.00      .40     2.00   .105+15  .000    .000      .000
    4.00    8.00      .80     2.00   .420+15  .000    .000      .000
    4.00    8.00     1.60     2.00   .168+16  .000    .000      .000
    4.00   40.00     2.00    10.00   .263+16  .000    .000      .000
    4.00   40.00     4.00    10.00   .105+17  .000    .000      .000
    4.00   40.00     8.00    10.00   .420+17  .000    .000      .000
   24.00    1.00      .05      .04   .164+13  .112-06 .119-06   .994+00
   24.00    1.00      .10      .04   .657+13  .775-07 .998-07   .832+00
   24.00    1.00      .20      .04   .263+14  .172-07 .548-07   .457+00
   24.00    8.00      .40      .33   .105+15  .110-16 .117-16   .971-10
   24.00    8.00      .80      .33   .420+15  .753-17 .975-17   .813-10
   24.00    8.00     1.60      .33   .168+16  .168-17 .536-17   .447-10
   24.00   40.00     2.00     1.67   .263+16  .000    .000      .000
   24.00   40.00     4.00     1.67   .105+17  .000    .000      .000
   24.00   40.00     8.00     1.67   .420+17  .000    .000      .000
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Down-current Distribution, BREACH-OF-CONTAINMENT Accident, Batch Release

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RADIONUCLIDE   SR 89
HALF LIFE    .527+02 DAYS
TOTAL RELEASE  .254+01 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .800-05 GRAMS PER CC
MAXIMUM PERMISSIBLE                                   .790-05     .110+04
DAUGHTER OF PREVIOUS RADIONUCLIDE, DECAY FRACTION =  1.0000

 CURRENT     DOWN   RADIUS     TIME    VOLUME    CONCENTRATION AVE.SPEC.
VELOCITY  CURRENT                                 ISO-    AVE.  ACTIVITY
  NM/DAY       NM       NM     DAYS        CC   UCI/CC  UCI/CC    UCI/GM
     .50     1.00      .05     2.00   .164+13  .166-06 .177-06   .221-01
     .50     1.00      .10     2.00   .657+13  .114-06 .148-06   .185-01
     .50     1.00      .20     2.00   .263+14  .255-07 .815-07   .102-01
     .50     8.00      .40    16.00   .105+15  .216-08 .230-08   .288-03
     .50     8.00      .80    16.00   .420+15  .149-08 .193-08   .241-03
     .50     8.00     1.60    16.00   .168+16  .332-09 .106-08   .132-03
     .50    40.00     2.00    80.00   .263+16  .373-10 .397-10   .496-05
     .50    40.00     4.00    80.00   .105+17  .254-10 .332-10   .415-05
     .50    40.00     8.00    80.00   .420+17  .572-11 .183-10   .228-05
    4.00     1.00      .05      .25   .164+13  .170-06 .181-06   .227-01
    4.00     1.00      .10      .25   .657+13  .117-06 .152-06   .190-01
    4.00     1.00      .20      .25   .263+14  .261-07 .833-07   .104-01
    4.00     8.00      .40     2.00   .105+15  .240-08 .277-08   .346-03
    4.00     8.00      .80     2.00   .420+15  .179-08 .232-08   .290-03
    4.00     8.00     1.60     2.00   .168+16  .399-09 .127-08   .159-03
    4.00    40.00     2.00    10.00   .263+16  .937-10 .996-10   .125-04
    4.00    40.00     4.00    10.00   .105+17  .644-10 .834-10   .104-04
    4.00    40.00     8.00    10.00   .420+17  .144-10 .458-10   .573-05
   24.00     1.00      .05      .04   .164+13  .171-06 .182-06   .227-01
   24.00     1.00      .10      .04   .657+13  .117-06 .152-06   .190-01
   24.00     1.00      .20      .04   .263+14  .242-07 .836-07   .104-01
   24.00     8.00      .40      .33   .105+15  .246-08 .283-08   .354-03
   24.00     8.00      .80      .33   .420+15  .183-08 .237-08   .296-03
   24.00     8.00     1.60      .33   .168+16  .408-09 .130-08   .163-03
   24.00    40.00     2.00     1.67   .263+16  .105-09 .111-09   .139-04
   24.00    40.00     4.00     1.67   .105+17  .718-10 .931-10   .116-04
   24.00    40.00     8.00     1.67   .420+17  .160-10 .511-10   .639-05
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RADIONUCLIDE   SR 90
HALF LIFE    .101+05 DAYS
TOTAL RELEASE  .120+00 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .800-05 GRAMS PER CC
MAXIMUM PERMISSIBLE                                   .790-07     .420+01

 CURRENT     DOWN   RADIUS     TIME    VOLUME    CONCENTRATION AVE.SPEC.
VELOCITY  CURRENT                                 ISO-    AVE.  ACTIVITY
  NM/DAY       NM       NM     DAYS        CC   UCI/CC  UCI/CC    UCI/GM
     .50     1.00      .05     2.00   .164+13  .906-08 .857-08   .107-02
     .50     1.00      .10     2.00   .657+13  .554-08 .718-08   .897-03
     .50     1.00      .20     2.00   .263+14  .124-08 .399-08   .493-03
     .50     8.00      .40    16.00   .105+15  .126-09 .139-09   .167-04
     .50     8.00      .80    16.00   .420+15  .464-10 .112-09   .140-04
     .50     8.00     1.60    16.00   .168+16  .193-10 .615-10   .769-05
     .50    40.00     2.00    80.00   .263+16  .501-11 .533-11   .666-06
     .50    40.00     4.00    80.00   .105+17  .344-11 .446-11   .558-06
     .50    40.00     8.00    80.00   .420+17  .768-12 .245-11   .306-06
    4.00     1.00      .05      .25   .164+13  .906-08 .857-08   .107-02
    4.00     1.00      .10      .25   .657+13  .554-08 .718-08   .897-03
    4.00     1.00      .20      .25   .263+14  .124-08 .399-08   .493-03
    4.00     8.00      .40     2.00   .105+15  .126-09 .139-09   .167-04
    4.00     8.00      .80     2.00   .420+15  .465-10 .112-09   .140-04
    4.00     8.00     1.60     2.00   .168+16  .193-10 .616-10   .770-05
    4.00    40.00     2.00    10.00   .263+16  .503-11 .535-11   .669-06
    4.00    40.00     4.00    10.00   .105+17  .346-11 .448-11   .560-06
    4.00    40.00     8.00    10.00   .420+17  .772-12 .246-11   .308-06
   24.00     1.00      .05      .04   .164+13  .906-08 .857-08   .107-02
   24.00     1.00      .10      .04   .657+13  .554-08 .718-08   .897-03
   24.00     1.00      .20      .04   .263+14  .124-08 .399-08   .493-03
   24.00     8.00      .40      .33   .105+15  .126-09 .139-09   .167-04
   24.00     8.00      .80      .33   .420+15  .465-10 .112-09   .140-04
   24.00     8.00     1.60      .33   .168+16  .193-10 .616-10   .770-05
   24.00    40.00     2.00     1.67   .263+16  .504-11 .536-11   .670-06
   24.00    40.00     4.00     1.67   .105+17  .346-11 .449-11   .561-06
   24.00    40.00     8.00     1.67   .420+17  .772-12 .246-11   .308-06
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Down-current Distribution, BREACH-OF-CONTAINMENT Accident, Batch Release

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RADIONUCLIDE   Y  90
HALF LIFE   .267+01 DAYS
TOTAL RELEASE  .416+00 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .300-09 GRAMS PER CC
MAXIMUM PERMISSIBLE                                  .380-06      .300+05
DAUGHTER OF PREVIOUS RADIONUCLIDE, DECAY FRACTION =  1.0000

 CURRENT    DOWN   RADIUS     TIME    VOLUME    CONCENTRATION AVE.SPEC.
VELOCITY CURRENT                                   ISO-    AVE.  ACTIVITY
  NM/DAY      NM       NM     DAYS          CC   UCI/CC  UCI/CC    UCI/GM
     .50    1.00      .05     2.00   .164+13  .199-07 .212-07   .705+02
     .50    1.00      .10     2.00   .657+13  .137-07 .177-07   .590+02
     .50    1.00      .20     2.00   .263+14  .305-08 .973-08   .324+02
     .50    9.00      .40    16.00   .105+15  .131-09 .139-09   .463+00
     .50    8.00      .80    16.00   .420+15  .898-10 .116-09   .388+00
     .50    8.00     1.60    16.00   .168+16  .200-10 .639-10   .213+00
     .50   40.00     2.00    80.00   .263+16  .501-11 .533-11   .178-01
     .50   40.00     4.00    80.00   .105+17  .344-11 .446-11   .149-01
     .50   40.00     8.00    80.00   .420+17  .765-12 .245-11   .817-02
    4.00    1.00      .05      .25   .164+13  .267-07 .284-07   .946+02
    4.00    1.00      .10      .25   .657+13  .183-07 .238-07   .792+02
    4.00    1.00      .20      .25   .263+14  .409-08 .131-07   .435+02
    4.00    8.00      .40     2.00   .105+15  .311-09 .331-09   .110+01
    4.00    8.00      .80     2.00   .420+15  .214-09 .277-09   .922+00
    4.00    8.00     1.60     2.00   .168+16  .477-10 .152-09   .507+00
    4.00   40.00     2.00    10.00   .263+16  .594-11 .634-11   .211-01
    4.00   40.00     4.00    10.00   .105+17  .410-11 .531-11   .177-01
    4.00   40.00     8.00    10.00   .420+17  .914-12 .292-11   .972-02
   24.00    1.00      .05      .04   .164+13  .277-07 .295-07   .983+02
   24.00    1.00      .10      .04   .657+13  .191-07 .247-07   .823+02
   24.00    1.00      .20      .04   .263+14  .425-09 .136-07   .452+02
   24.00    8.00      .40      .33   .105+15  .411-09 .437-09   .146+01
   24.00    8.00      .80      .33   .420+15  .282-09 .366-09   .122+01
   24.00    8.00     1.60      .33   .168+16  .630-10 .201-09   .670+00
   24.00   40.00     2.00     1.67   .263+16  .131-10 .139-10   .464-01
   24.00   40.00     4.00     1.67   .105+17  .900-11 .117-10   .389-01
   24.00   40.00     9.00     1.67   .420+17  .201-11 .641-11   .214-01
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RADIONUCLIDE   SR 91
HALF LIFE   .403+00 DAYS
TOTAL RELEASE  .151+01 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .800-05 GRAMS PER CC
MAXIMUM PERMISSIBLE                                 .400-04      .780+05

 CURRENT    DOWN   RADIUS     TIME    VOLUME    CONCENTRATION AVE.SPEC.
VELOCITY CURRENT                                   ISO-    AVE.  ACTIVITY
  NM/DAY      NM       NM     DAYS          CC   UCI/CC  UCI/CC    UCI/GM
     .50    1.00      .05     2.00   .164+13  .325-08 .346-08   .433-03
     .50    1.00      .10     2.00   .657+13  .224-08 .290-08   .362-03
     .50    1.00      .20     2.00   .263+14  .499-09 .159-08   .199-03
     .50    8.00      .40    16.00   .105+15  .178-20 .190-20   .237-15
     .50    8.00      .80    16.00   .420+15  .172-20 .159-20   .198-15
     .50    8.00     1.60    16.00   .168+16  .273-21 .872-21   .109-15
     .50   40.00     2.00    80.00   .263+16  .000    .000      .000
     .50   40.00     4.00    80.00   .105+17  .000    .000      .000
     .50   40.00     8.00    80.00   .420+17  .000    .000      .000
    4.00    1.00      .05      .25   .164+13  .660-07 .702-07   .877-02
    4.00    1.00      .10      .25   .657+13  .453-07 .588-07   .734-02
    4.00    1.00      .20      .25   .263+14  .101-07 .323-07   .403-02
    4.00    8.00      .40     2.00   .105+15  .508-10 .541-10   .676-05
    4.00    8.00      .80     2.00   .420+15  .349-10 .453-10   .566-05
    4.00    8.00     1.60     2.00   .168+16  .780-11 .249-10   .311-05
    4.00   40.00     2.00    10.00   .263+16  .216-17 .229-17   .287-12
    4.00   40.00     4.00    10.00   .105+17  .148-17 .192-17   .240-12
    4.00   40.00     8.00    10.00   .420+17  .331-18 .106-17   .132-12
   24.00    1.00      .05      .04   .164+13  .944-07 .100-06   .126-01
   24.00    1.00      .10      .04   .657+13  .649-07 .841-07   .105-01
   24.00    1.00      .20      .04   .263+14  .145-07 .462-07   .577-02
   24.00    8.00      .40      .33   .105+15  .893-09 .950-09   .119-03
   24.00    8.00      .80      .33   .420+15  .614-09 .795-09   .994-04
   24.00    8.00     1.60      .33   .168+16  .137-09 .437-09   .546-04
   24.00   40.00     2.00     1.67   .263+16  .361-11 .384-11   .480-06
   24.00   40.00     4.00     1.67   .105+17  .248-11 .321-11   .402-06
   24.00   40.00     8.00     1.67   .420+17  .553-12 .177-11   .221-06
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Down-current Distribution, BREACH-OF-CONTAINMENT Accident, Batch Release

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RADIONUCLIDE    Y  91
HALF LIFE    .588+02 DAYS
TOTAL RELEASE  .106+03 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .100-09 GRAMS PER CC
MAXIMUM PERMISSIBLE                                    .570-06     .230+04
DAUGHTER OF PREVIOUS RADIONUCLIDE, DECAY FRACTION =  1.0000

 CURRENT     DOWN   RADIUS     TIME    VOLUME    CONCENTRATION AVE.SPEC.
VELOCITY  CURRENT                                  ISO-    AVE.  ACTIVITY
  NM/DAY       NM       NM     DAYS        CC    UCI/CC  UCI/CC    UCI/GM
     .50     1.00      .05     2.00   .164+13  .695-05 .740-05   .247+05
     .50     1.00      .10     2.00   .657+13  .478-05 .619-05   .206+05
     .50     1.00      .20     2.00   .263+14  .107-05 .340-05   .113+05
     .50     8.00      .40    16.00   .105+15  .921-07 .980-07   .327+03
     .50     8.00      .80    16.00   .420+15  .633-07 .820-07   .273+03
     .50     8.00     1.60    16.00   .168+16  .141-07 .451-07   .150+03
     .50    40.00     2.00    80.00   .263+16  .173-08 .184-08   .615+01
     .50    40.00     4.00    80.00   .105+17  .119-08 .154-08   .514+01
     .50    40.00     8.00    80.00   .420+17  .266-09 .848-09   .283+01
    4.00     1.00      .05      .25   .164+13  .710-05 .755-05   .252+05
    4.00     1.00      .10      .25   .657+13  .488-05 .632-05   .211+05
    4.00     1.00      .20      .25   .263+14  .109-05 .347-05   .116+05
    4.00     8.00      .40     2.00   .105+15  .109-06 .116-06   .385+03
    4.00     8.00      .80     2.00   .420+15  .747-07 .969-07   .323+03
    4.00     8.00     1.60     2.00   .168+16  .167-07 .532-07   .177+03
    4.00    40.00     2.00    10.00   .263+16  .395-08 .421-08   .140+02
    4.00    40.00     4.00    10.00   .105+17  .272-08 .352-08   .117+02
    4.00    40.00     8.00    10.00   .420+17  .607-09 .193-08   .645+01
   24.00     1.00      .05      .04   .164+13  .712-05 .757-05   .252+05
   24.00     1.00      .10      .04   .657+13  .489-05 .634-05   .211+05
   24.00     1.00      .20      .04   .263+14  .109-05 .348-05   .116+05
   24.00     8.00      .40      .33   .105+15  .111-06 .118-06   .393+03
   24.00     8.00      .80      .33   .420+15  .762-07 .987-07   .329+03
   24.00     8.00     1.60      .33   .168+16  .170-07 .542-07   .181+03
   24.00    40.00     2.00     1.67   .263+16  .436-08 .464-08   .155+02
   24.00    40.00     4.00     1.67   .105+17  .300-08 .389-08   .130+02
   24.00    40.00     8.00     1.67   .420+17  .669-09 .213-08   .712+01
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RADIONUCLIDE    Y  93
HALF LIFE    .420+00 DAYS
TOTAL RELEASE  .138+01 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .300-09 GRAMS PER CC
MAXIMUM PERMISSIBLE                                    .570-06     .130+06

 CURRENT     DOAN   RADIUS     TIME    VOLUME    CONCENTRATION AVE.SPEC.
VELOCITY  CURRENT                                  ISO-    AVE.  ACTIVITY
  NM/DAY       NM       NM     DAYS        CC    UCI/CC  UCI/CC    UCI/GM
     .50     1.00      .05     2.00   .164+13  .366-08 .390-08   .130+02
     .50     1.00      .10     2.00   .657+13  .252-08 .326-08   .109+02
     .50     1.00      .20     2.00   .263+14  .562-09 .179-08   .597+01
     .50     8.00      .40    16.00   .105+15  .863-20 .918-20   .306-10
     .50     8.00      .80    16.00   .420+15  .593-20 .768-20   .256-10
     .50     8.00     1.60    16.00   .168+16  .132-20 .422-20   .141-10
     .50    40.00     2.00    80.00   .263+16  .000    .000      .000
     .50    40.00     4.00    80.00   .105+17  .000    .000      .000
     .50    40.00     8.00    80.00   .420+17  .000    .000      .000
    4.00     1.00      .05      .25   .164+13  .619-07 .658-07   .219+03
    4.00     1.00      .10      .25   .657+13  .425-07 .551-07   .184+03
    4.00     1.00      .20      .25   .263+14  .949-08 .303-07   .101+03
    4.00     8.00      .40     2.00   .105+15  .572-10 .609-10   .203+00
    4.00     8.00      .80     2.00   .420+15  .393-10 .510-10   .170+00
    4.00     8.00     1.60     2.00   .168+16  .878-11 .280-10   .933-01
    4.00    40.00     2.00    10.00   .243+16  .559-17 .595-17   .198-07
    4.00    40.00     4.00    10.00   .105+17  .384-17 .498-17   .166-07
    4.00    40.00     8.00    10.00   .420+17  .857-18 .273-17   .911-08
   24.00     1.00      .05      .04   .164+13  .866-07 .922-07   .307+03
   24.00     1.00      .10      .04   .657+13  .596-07 .772-07   .257+03
   24.00     1.00      .20      .04   .263+14  .133-07 .424-07   .141+03
   24.00     8.00      .40      .33   .105+15  .845-09 .899-09   .300+01
   24.00     8.00      .80      .33   .420+15  .581-09 .753-09   .251+01
   24.00     8.00     1.60      .33   .168+16  .130-09 .414-09   .138+01
   24.00    40.00     2.00     1.67   .263+16  .392-11 .417-11   .139-01
   24.00    40.00     4.00     1.67   .105+17  .270-11 .349-11   .116-01
   24.00    40.00     8.00     1.67   .420+17  .602-12 .192-11   .640-02
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Down-current Distribution, BREACH-OF-CONTAINMENT Accident, Batch Release

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RADIONUCLIDE   ZR 95
HALF LIFE    .655+02 DAYS
TOTAL RELEASE  .317-03 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .220-10 GRAMS PER CC
MAXIMUM PERMISSIBLE                                  .950-06     .100+09

 CURRENT     DOWN  RADIUS     TIME    VOLUME    CONCENTRATION AVE.SPEC.
VELOCITY CURRENT                                   ISO-    AVE.  ACTIVITY
  NM/DAY      NM      NM     DAYS        CC     UCI/CC  UCI/CC    UCI/GM
     .50    1.00     .05     2.00  .164+13  .208-10 .222-10   .101+01
     .50    1.00     .10     2.00  .657+13  .143-10 .186-10   .844+00
     .50    1.00     .20     2.00  .263+14  .320-11 .102-10   .464+00
     .50    8.00     .40    16.00  .105+15  .241-12 .299-12   .136-01
     .50    8.00     .80    16.00  .420+15  .193-12 .250-12   .114-01
     .50    8.00    1.60    16.00  .168+16  .431-13 .137-12   .625-02
     .50   40.00    2.00    80.00  .263+16  .571-14 .607-14   .276-03
     .50   40.00    4.00    80.00  .105+17  .392-14 .508-14   .231-03
     .50   40.00    8.00    80.00  .420+17  .875-15 .279-14   .127-03
    4.00    1.00     .05      .25  .164+13  .212-10 .226-10   .103+01
    4.00    1.00     .10      .25  .657+13  .146-10 .189-10   .859+00
    4.00    1.00     .20      .25  .263+14  .326-11 .104-10   .472+00
    4.00    8.00     .40     2.00  .105+15  .376-12 .346-12   .157-01
    4.00    8.00     .80     2.00  .420+15  .224-12 .290-12   .132-01
    4.00    8.00    1.60     2.00  .168+16  .499-13 .159-12   .724-02
    4.00   40.00    2.00    10.00  .263+16  .120-13 .127-13   .579-03
    4.00   40.00    4.00    10.00  .105+17  .923-14 .107-13   .485-03
    4.00   40.00    8.00    10.00  .420+17  .184-14 .586-14   .266-03
   24.00    1.00     .05      .04  .164+13  .213-10 .226-10   .103+01
   24.00    1.00     .10      .04  .657+13  .146-10 .190-10   .861+00
   24.00    1.00     .20      .04  .263+14  .326-11 .104-10   .473+00
   24.00    8.00     .40      .33  .105+15  .331-12 .353-12   .160-01
   24.00    8.00     .80      .33  .420+15  .228-12 .295-12   .134-01
   24.00    8.00    1.60      .33  .168+16  .508-13 .162-12   .737-02
   24.00   40.00    2.00     1.67  .263+16  .131-13 .139-13   .632-03
   24.00   40.00    4.00     1.67  .105+17  .899-14 .116-13   .529-03
   24.00   40.00    8.00     1.67  .420+17  .200-14 .640-14   .291-03
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RADIONUCLIDE   NB 95
HALF LIFE    .350+02 DAYS
TOTAL RELEASE  .283+01 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .100-10 GRAMS PER CC
MAXIMUM PERMISSIBLE                                  .950-06     .100+09
DAUGHTER OF PREVIOUS RADIONUCLIDE, DECAY FRACTION =  1.0000

 CURRENT     DOWN  RADIUS     TIME    VOLUME    CONCENTRATION AVE.SPEC.
VELOCITY CURRENT                                   ISO-    AVE.  ACTIVITY
  NM/DAY      NM      NM     DAYS        CC     UCI/CC  UCI/CC    UCI/GM
     .50    1.00     .05     2.00  .164+13  .183-06 .194-06   .194+05
     .50    1.00     .10     2.00  .657+13  .176-06 .163-06   .163+05
     .50    1.00     .20     2.00  .263+14  .280-07 .894-07   .894+04
     .50    8.00     .40    16.00  .105+15  .216-08 .230-08   .230+03
     .50    8.00     .80    16.00  .420+15  .149-08 .193-08   .193+03
     .50    8.00    1.60    16.00  .168+16  .332-09 .106-08   .106+03
     .50   40.00    2.00    80.00  .263+16  .244-10 .259-10   .259+01
     .50   40.00    4.00    80.00  .105+17  .168-10 .217-10   .217+01
     .50   40.00    8.00    80.00  .420+17  .374-11 .119-10   .119+01
    4.00    1.00     .05      .25  .164+13  .189-06 .201-06   .201+05
    4.00    1.00     .10      .25  .657+13  .130-06 .168-06   .168+05
    4.00    1.00     .20      .25  .263+14  .290-07 .925-07   .925+04
    4.00    8.00     .40     2.00  .105+15  .285-08 .304-08   .304+03
    4.00    8.00     .80     2.00  .420+15  .196-08 .254-08   .254+03
    4.00    8.00    1.60     2.00  .168+16  .938-09 .190-08   .190+03
    4.00   40.00    2.00    10.00  .263+16  .975-10 .104-09   .104+02
    4.00   40.00    4.00    10.00  .105+17  .670-10 .868-10   .868+01
    4.00   40.00    8.00    10.00  .420+17  .149-10 .477-10   .477+01
   24.00    1.00     .05      .04  .164+13  .190-06 .202-06   .202+05
   24.00    1.00     .10      .04  .657+13  .131-06 .169-06   .169+05
   24.00    1.00     .20      .04  .263+14  .291-07 .929-07   .929+04
   24.00    8.00     .40      .33  .105+15  .295-08 .314-08   .314+03
   24.00    8.00     .80      .33  .420+15  .203-08 .263-08   .263+03
   24.00    8.00    1.60      .33  .168+16  .452-09 .144-08   .144+03
   24.00   40.00    2.00     1.67  .263+16  .115-09 .122-09   .122+02
   24.00   40.00    4.00     1.67  .105+17  .790-10 .102-09   .102+02
   24.00   40.00    8.00     1.67  .420+17  .176-10 .562-10   .562+01
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Down-current Distribution, BREACH-OF-CONTAINMENT Accident, Batch Release

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RADIONUCLIDE   ZR 97
HALF LIFE    .708+00 DAYS
TOTAL RELEASE  .119+01 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .220-10 GRAMS PER CC
MAXIMUM PERMISSIBLE                                .320-06     .180+05

 CURRENT     DOWN  RADIUS     TIME    VOLUME    CONCENTRATION AVE.SPEC.
VELOCITY  CURRENT                                 ISO-    AVE.  ACTIVITY
  NM/DAY       NM      NM     DAYS        CC    UCI/CC  UCI/CC    UCI/GM
     .50     1.00     .05     2.00  .164+13  .113-07 .120-07   .546+03
     .50     1.00     .10     2.00  .657+13  .776-08 .100-07   .457+03
     .50     1.00     .20     2.00  .263+14  .173-08 .552-08   .251+03
     .50     8.00     .40    16.00  .105+15  .197-15 .210-15   .954-05
     .50     8.00     .80    16.00  .420+15  .136-15 .176-15   .798-05
     .50     8.00    1.60    16.00  .168+16  .302-16 .965-16   .439-05
     .50    40.00    2.00    80.00  .263+16  .000    .000      .000
     .50    40.00    4.00    80.00  .105+17  .000    .000      .000
     .50    40.00    8.00    80.00  .420+17  .000    .000      .000
    4.00     1.00     .05      .25  .164+13  .626-07 .666-07   .303+04
    4.00     1.00     .10      .25  .657+13  .430-07 .557-07   .253+04
    4.00     1.00     .20      .25  .263+14  .960-08 .306-07   .139+04
    4.00     8.00     .40     2.00  .105+15  .176-09 .188-09   .853+01
    4.00     8.00     .80     2.00  .420+15  .121-09 .157-09   .714+01
    4.00     8.00    1.60     2.00  .168+16  .270-10 .863-10   .392+01
    4.00    40.00    2.00    10.00  .263+16  .280-14 .298-14   .136-03
    4.00    40.00    4.00    10.00  .105+17  .193-14 .250-14   .113-03
    4.00    40.00    8.00    10.00  .420+17  .430-15 .137-14   .623-04
   24.00     1.00     .05      .04  .164+13  .767-07 .816-07   .371+04
   24.00     1.00     .10      .04  .657+13  .577-07 .683-07   .311+04
   24.00     1.00     .20      .04  .263+14  .118-07 .375-07   .171+04
   24.00     8.00     .40      .33  .105+15  .901-09 .959-09   .436+02
   24.00     8.00     .80      .33  .420+15  .619-09 .802-09   .365+02
   24.00     8.00    1.60      .33  .168+16  .138-09 .441-09   .200+02
   24.00    40.00    2.00     1.67  .263+16  .977-11 .104-10   .473+00
   24.00    40.00    4.00     1.67  .105+17  .672-11 .870-11   .396+00
   24.00    40.00    8.00     1.67  .420+17  .150-11 .478-11   .217+00
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RADIONUCLIDE   MO 99
HALF LIFE    .278-01 DAYS
TOTAL RELEASE  .879-01 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .100-07 GRAMS PER CC
MAXIMUM PERMISSIBLE                                .750-06     .270+04

 CURRENT     DOWN  RADIUS     TIME    VOLUME    CONCENTRATION AVE.SPEC.
VELOCITY  CURRENT                                 ISO-    AVE.  ACTIVITY
  NM/DAY       NM      NM     DAYS        CC    UCI/CC  UCI/CC    UCI/GM
     .50     1.00     .05     2.00  .164+13  .359-08 .381-08   .381+00
     .50     1.00     .10     2.00  .657+13  .246-08 .319-08   .319+00
     .50     1.00     .20     2.00  .263+14  .550-09 .175-08   .175+00
     .50     8.00     .40    16.00  .105+15  .171-11 .182-11   .182-03
     .50     8.00     .80    16.00  .420+15  .117-11 .152-11   .152-03
     .50     8.00    1.60    16.00  .168+16  .262-12 .836-12   .836-04
     .50    40.00    2.00    80.00  .263+16  .806-20 .857-20   .857-12
     .50    40.00    4.00    80.00  .105+17  .554-20 .717-20   .717-12
     .50    40.00    8.00    80.00  .420+17  .124-20 .394-20   .394-12
    4.00     1.00     .05      .25  .164+13  .555-08 .590-08   .590+00
    4.00     1.00     .10      .25  .657+13  .381-08 .494-08   .494+00
    4.00     1.00     .20      .25  .263+14  .851-09 .271-08   .271+00
    4.00     8.00     .40     2.00  .105+15  .560-10 .596-10   .596-02
    4.00     8.00     .80     2.00  .420+15  .385-10 .499-10   .499-02
    4.00     8.00    1.60     2.00  .168+16  .859-11 .274-10   .274-02
    4.00    40.00    2.00    10.00  .263+16  .305-12 .324-12   .324-04
    4.00    40.00    4.00    10.00  .105+17  .210-12 .272-12   .272-04
    4.00    40.00    8.00    10.00  .420+17  .468-13 .149-12   .149-04
   24.00     1.00     .05      .04  .164+13  .584-08 .621-08   .621+00
   24.00     1.00     .10      .04  .657+13  .402-08 .520-08   .520+00
   24.00     1.00     .20      .04  .263+14  .896-09 .286-08   .286+00
   24.00     8.00     .40      .33  .105+15  .849-10 .903-10   .903-02
   24.00     8.00     .80      .33  .420+15  .583-10 .756-10   .756-02
   24.00     8.00    1.60      .33  .168+16  .130-10 .415-10   .415-02
   24.00    40.00    2.00     1.67  .263+16  .244-11 .259-11   .259-03
   24.00    40.00    4.00     1.67  .105+17  .167-11 .217-11   .217-03
   24.00    40.00    8.00     1.67  .420+17  .373-12 .119-11   .119-03
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Down-current Distribution, BREACH-OF-CONTAINMENT Accident, Batch Release

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RADIONUCLIDE   RU 103
HALF LIFE   .395+02 DAYS
TOTAL RELEASE  .208+01 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .000    GRAMS PER CC
MAXIMUM PERMISSIBLE                                  .130-05     .000

 CURRENT    DOWN  RADIUS    TIME    VOLUME    CONCENTRATION AVE.SPEC.
VELOCITY CURRENT                                  ISO-   AVE.  ACTIVITY
  NM/DAY      NM      NM    DAYS        CC     UCI/CC  UCI/CC    UCI/GM
     .50    1.00     .05    2.00   .164+13   .135-06 .143-06    .000
     .50    1.00     .10    2.00   .657+13   .927-07 .120-06    .000
     .50    1.00     .20    2.00   .263+14   .207-07 .660-07    .000
     .50    8.00     .40   16.00   .105+15   .165-08 .175-08    .000
     .50    8.00     .80   16.00   .420+15   .113-08 .147-08    .000
     .50    8.00    1.60   16.00   .168+16   .253-09 .807-09    .000
     .50   40.00    2.00   80.00   .263+16   .215-10 .228-10    .000
     .50   40.00    4.00   80.00   .105+17   .147-10 .191-10    .000
     .50   40.00    8.00   80.00   .420+17   .329-11 .105-10    .000
    4.00    1.00     .05     .25   .164+13   .139-06 .148-06    .000
    4.00    1.00     .10     .25   .657+13   .956-07 .124-06    .000
    4.00    1.00     .20     .25   .263+14   .213-07 .680-07    .000
    4.00    8.00     .40    2.00   .105+15   .211-08 .224-08    .000
    4.00    8.00     .80    2.00   .420+15   .145-08 .188-08    .000
    4.00    8.00    1.60    2.00   .168+16   .323-09 .103-08    .000
    4.00   40.00    2.00   10.00   .263+16   .733-10 .779-10    .000
    4.00   40.00    4.00   10.00   .105+17   .503-10 .652-10    .000
    4.00   40.00    8.00   10.00   .420+17   .112-10 .358-10    .000
   24.00    1.00     .05     .04   .164+13   .140-06 .148-06    .000
   24.00    1.00     .10     .04   .657+13   .959-07 .124-06    .000
   24.00    1.00     .20     .04   .263+14   .214-07 .683-07    .000
   24.00    8.00     .40     .33   .105+15   .217-08 .231-08    .000
   24.00    8.00     .80     .33   .420+15   .149-08 .193-08    .000
   24.00    8.00    1.60     .33   .168+16   .333-09 .106-08    .000
   24.00   40.00    2.00    1.67   .263+16   .848-10 .902-10    .000
   24.00   40.00    4.00    1.67   .105+17   .593-10 .755-10    .000
   24.00   40.00    8.00    1.67   .420+17   .130-10 .415-10    .000
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RADIONUCLIDE   RH 105
HALF LIFE   .149+01 DAYS
TOTAL RELEASE  .293+00 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .000    GRAMS PER CC
MAXIMUM PERMISSIBLE                                  .190-05     .000

 CURRENT    DOWN  RADIUS    TIME    VOLUME    CONCENTRATION AVE.SPEC.
VELOCITY CURRENT                                  ISO-   AVE.  ACTIVITY
  NM/DAY      NM      NM    DAYS        CC     UCI/CC  UCI/CC    UCI/GM
     .50    1.00     .05    2.00   .164+13   .779-08 .828-08    .000
     .50    1.00     .10    2.00   .657+13   .535-08 .693-08    .000
     .50    1.00     .20    2.00   .263+14   .119-08 .381-08    .000
     .50    8.00     .40   16.00   .105+15   .185-12 .197-12    .000
     .50    8.00     .80   16.00   .420+15   .127-12 .165-12    .000
     .50    8.00    1.60   16.00   .168+16   .283-13 .909-13    .000
     .50   40.00    2.00   80.00   .263+16   .765-27 .103-26    .000
     .50   40.00    4.00   80.00   .105+17   .663-27 .860-27    .000
     .50   40.00    8.00   80.00   .420+17   .148-27 .472-27    .000
    4.00    1.00     .05     .25   .164+13   .175-07 .186-07    .000
    4.00    1.00     .10     .25   .657+13   .120-07 .156-07    .000
    4.00    1.00     .20     .25   .263+14   .269-08 .857-08    .000
    4.00    8.00     .40    2.00   .105+15   .122-09 .129-09    .000
    4.00    8.00     .80    2.00   .420+15   .836-10 .108-09    .000
    4.00    8.00    1.60    2.00   .168+16   .187-10 .595-10    .000
    4.00   40.00    2.00   10.00   .263+16   .119-12 .127-12    .000
    4.00   40.00    4.00   10.00   .105+17   .920-13 .106-12    .000
    4.00   40.00    8.00   10.00   .420+17   .183-13 .589-13    .000
   24.00    1.00     .05     .04   .164+13   .193-07 .205-07    .000
   24.00    1.00     .10     .04   .657+13   .133-07 .172-07    .000
   24.00    1.00     .20     .04   .263+14   .296-08 .944-08    .000
   24.00    8.00     .40     .33   .105+15   .263-09 .280-09    .000
   24.00    8.00     .80     .33   .420+15   .181-09 .235-09    .000
   24.00    8.00    1.60     .33   .168+16   .404-10 .129-09    .000
   24.00   40.00    2.00    1.67   .263+16   .548-11 .609-11    .000
   24.00   40.00    4.00    1.67   .105+17   .390-11 .506-11    .000
   24.00   40.00    8.00    1.67   .420+17   .871-12 .278-11    .000
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Down-current Distribution, BREACH-OF-CONTAINMENT Accident, Batch Release

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RADIONUCLIDE    RU 106
HALF LIFE    .369+03 DAYS
TOTAL RELEASE   .120+00 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .000    GRAMS PER CC
MAXIMUM PERMISSIBLE
                                                      .160-06     .000

 CURRENT     DOWN   RADIUS     TIME    VOLUME    CONCENTRATION AVE.SPEC.
VELOCITY CURRENT                                    150-    AVE.  ACTIVITY
 NM/DAY       NM        NM     DAYS          CC   UCI/CC  UCI/CC    UCI/GM
     .50    1.00       .05     2.00   .164+13  .803-08 .854-08    .000
     .50    1.00       .10     2.00   .657+13  .552-08 .715-08    .000
     .50    1.00       .20     2.00   .263+14  .173-08 .393-08    .000
     .50    8.00       .40    16.00   .105+15  .122-09 .130-09    .000
     .50    8.00       .80    16.00   .420+15  .849-10 .109-09    .000
     .50    8.00      1.60    16.00   .168+16  .187-10 .598-10    .000
     .50   40.00      2.00    80.00   .263+16  .433-11 .461-11    .000
     .50   40.00      4.00    80.00   .105+17  .298-11 .386-11    .000
     .50   40.00      8.00    80.00   .420+17  .664-12 .212-11    .000
    4.00    1.00       .05      .25   .164+13  .806-08 .857-08    .000
    4.00    1.00       .10      .25   .657+13  .554-08 .717-08    .000
    4.00    1.00       .20      .25   .263+14  .124-08 .394-08    .000
    4.00    8.00       .40     2.00   .105+15  .125-09 .133-09    .000
    4.00    8.00       .80     2.00   .420+15  .862-10 .112-09    .000
    4.00    8.00      1.60     2.00   .168+16  .192-10 .614-10    .000
    4.00   40.00      2.00    10.00   .263+16  .494-11 .526-11    .000
    4.00   40.00      4.00    10.00   .105+17  .340-11 .440-11    .000
    4.00   40.00      8.00    10.00   .420+17  .758-12 .242-11    .000
   24.00    1.00       .05      .04   .164+13  .806-08 .857-08    .000
   24.00    1.00       .10      .04   .657+13  .554-08 .718-08    .000
   24.00    1.00       .20      .04   .263+14  .124-08 .394-08    .000
   24.00    8.00       .40      .33   .105+15  .126-09 .134-09    .000
   24.00    8.00       .80      .33   .420+15  .865-10 .112-09    .000
   24.00    8.00      1.60      .33   .168+16  .193-10 .616-10    .000
   24.00   40.00      2.00     1.67   .263+16  .502-11 .534-11    .000
   24.00   40.00      4.00     1.67   .105+17  .345-11 .447-11    .000
   24.00   40.00      8.00     1.67   .420+17  .770-12 .246-11    .000
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RADIONUCLIDE    PD 109
HALF LIFE    .561+00 DAYS
TOTAL RELEASE   .571-02 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .000    GRAMS PER CC
MAXIMUM PERMISSIBLE
                                                      .130-05     .000

 CURRENT     DOWN   RADIUS     TIME    VOLUME    CONCENTRATION AVE.SPEC.
VELOCITY CURRENT                                    150-    AVE.  ACTIVITY
 NM/DAY       NM        NM     DAYS          CC   UCI/CC  UCI/CC    UCI/GM
     .50    1.00       .05     2.00   .164+13  .324-10 .345-10    .000
     .50    1.00       .10     2.00   .657+13  .223-10 .289-10    .000
     .50    1.00       .20     2.00   .263+14  .497-11 .159-10    .000
     .50    8.00       .40    16.00   .105+15  .156-19 .166-19    .000
     .50    8.00       .80    16.00   .420+15  .107-19 .139-19    .000
     .50    8.00      1.60    16.00   .168+16  .240-20 .765-20    .000
     .50   40.00      2.00    80.00   .263+16  .000    .000       .000
     .50   40.00      4.00    80.00   .105+17  .000    .000       .000
     .50   40.00      8.00    80.00   .420+17  .000    .000       .000
    4.00    1.00       .05      .25   .164+13  .282-09 .300-09    .000
    4.00    1.00       .10      .25   .657+13  .194-09 .251-09    .000
    4.00    1.00       .20      .25   .263+14  .432-10 .138-09    .000
    4.00    8.00       .40     2.00   .105+15  .507-12 .539-12    .000
    4.00    8.00       .80     2.00   .420+15  .348-12 .451-12    .000
    4.00    8.00      1.60     2.00   .168+16  .777-13 .248-12    .000
    4.00   40.00      2.00    10.00   .263+16  .103-17 .110-17    .000
    4.00   40.00      4.00    10.00   .105+17  .711-18 .921-18    .000
    4.00   40.00      8.00    10.00   .420+17  .159-18 .506-18    .000
   24.00    1.00       .05      .04   .164+13  .364-09 .387-09    .000
   24.00    1.00       .10      .04   .657+13  .250-09 .324-09    .000
   24.00    1.00       .20      .04   .263+14  .559-10 .178-09    .000
   24.00    8.00       .40      .33   .105+15  .397-11 .422-11    .000
   24.00    8.00       .80      .33   .420+15  .273-11 .353-11    .000
   24.00    8.00      1.60      .33   .168+16  .609-12 .199-11    .000
   24.00   40.00      2.00     1.67   .263+16  .306-13 .325-13    .000
   24.00   40.00      4.00     1.67   .105+17  .210-13 .272-13    .000
   24.00   40.00      8.00     1.67   .420+17  .469-14 .150-13    .000
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Down-current Distribution, BREACH-OF-CONTAINMENT Accident, Batch Release

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RADIONUCLIDE   AG 111
HALF LIFE   .750+01 DAYS
TOTAL RELEASE  .781-02 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .300-09 GRAMS PER CC
MAXIMUM PERMISSIBLE                                .150-07      .130+01

 CURRENT     DOWN   RADIUS     TIME    VOLUME    CONCENTRATION AVE.SPEC.
VELOCITY  CURRENT                                  ISO-    AVE.  ACTIVITY
  NM/DAY       NM       NM     DAYS         CC   UCI/CC  UCI/CC    UCI/GM
     .50     1.00      .05     2.00   .164+13  .436-09 .464-09   .155+01
     .50     1.00      .10     2.00   .657+13  .300-09 .388-09   .129+01
     .50     1.00      .20     2.00   .263+14  .669-10 .213-09   .711+00
     .50     8.00      .40    16.00   .105+15  .197-11 .199-11   .663-02
     .50     8.00      .80    16.00   .420+15  .128-11 .166-11   .555-02
     .50     8.00     1.60    16.00   .168+16  .287-12 .914-12   .305-02
     .50    40.00     2.00    80.00   .263+16  .202-15 .215-15   .716-06
     .50    40.00     4.00    80.00   .105+17  .139-15 .180-15   .600-06
     .50    40.00     8.00    80.00   .420+17  .310-16 .988-16   .329-06
    4.00     1.00      .05      .25   .164+13  .513-09 .545-09   .182+01
    4.00     1.00      .10      .25   .657+13  .352-09 .456-09   .152+01
    4.00     1.00      .20      .25   .263+14  .786-10 .251-09   .836+00
    4.00     8.00      .40     2.00   .105+15  .681-11 .725-11   .242-01
    4.00     8.00      .80     2.00   .420+15  .468-11 .607-11   .202-01
    4.00     8.00     1.60     2.00   .168+16  .104-11 .333-11   .111-01
    4.00    40.00     2.00    10.00   .263+16  .130-12 .138-12   .461-03
    4.00    40.00     4.00    10.00   .105+17  .894-13 .116-12   .386-03
    4.00    40.00     8.00    10.00   .420+17  .200-13 .637-13   .212-03
   24.00     1.00      .05      .04   .164+13  .522-09 .556-09   .185+01
   24.00     1.00      .10      .04   .657+13  .359-09 .465-09   .155+01
   24.00     1.00      .20      .04   .263+14  .801-10 .256-09   .852+00
   24.00     8.00      .40      .33   .105+15  .795-11 .845-11   .282-01
   24.00     8.00      .80      .33   .420+15  .546-11 .708-11   .236-01
   24.00     8.00     1.60      .33   .168+16  .122-11 .389-11   .130-01
   24.00    40.00     2.00     1.67   .263+16  .291-12 .299-12   .997-03
   24.00    40.00     4.00     1.67   .105+17  .193-12 .250-12   .834-03
   24.00    40.00     8.00     1.67   .420+17  .431-13 .137-12   .458-03
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RADIONUCLIDE   CD 115
HALF LIFE   .223+01 DAYS
TOTAL RELEASE  .111-02 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .110-09 GRAMS PER CC
MAXIMUM PERMISSIBLE                                .570-08      .710+03

 CURRENT     DOWN   RADIUS     TIME    VOLUME    CONCENTRATION AVE.SPEC.
VELOCITY  CURRENT                                  ISO-    AVE.  ACTIVITY
  NM/DAY       NM       NM     DAYS         CC   UCI/CC  UCI/CC    UCI/GM
     .50     1.00      .05     2.00   .164+13  .400-10 .426-10   .387+00
     .50     1.00      .10     2.00   .657+13  .275-10 .357-10   .324+00
     .50     1.00      .20     2.00   .263+14  .614-11 .196-10   .178+00
     .50     8.00      .40    16.00   .105+15  .807-14 .858-14   .780-04
     .50     8.00      .80    16.00   .420+15  .555-14 .719-14   .653-04
     .50     8.00     1.60    16.00   .168+16  .124-14 .395-14   .359-04
     .50    40.00     2.00    80.00   .263+16  .744-24 .791-24   .719-14
     .50    40.00     4.00    80.00   .105+17  .511-24 .662-24   .602-14
     .50    40.00     8.00    80.00   .420+17  .114-24 .364-24   .331-14
    4.00     1.00      .05      .25   .164+13  .690-10 .734-10   .667+00
    4.00     1.00      .10      .25   .657+13  .474-10 .614-10   .558+00
    4.00     1.00      .20      .25   .263+14  .106-10 .337-10   .307+00
    4.00     8.00      .40     2.00   .105+15  .624-12 .666-12   .605-02
    4.00     8.00      .80     2.00   .420+15  .430-12 .557-12   .507-02
    4.00     8.00     1.60     2.00   .168+16  .959-13 .306-12   .278-02
    4.00    40.00     2.00    10.00   .263+16  .208-14 .222-14   .201-04
    4.00    40.00     4.00    10.00   .105+17  .143-14 .185-14   .169-04
    4.00    40.00     8.00    10.00   .420+17  .319-15 .102-14   .926-05
   24.00     1.00      .05      .04   .164+13  .736-10 .783-10   .712+00
   24.00     1.00      .10      .04   .657+13  .506-10 .655-10   .596+00
   24.00     1.00      .20      .04   .263+14  .113-10 .360-10   .327+00
   24.00     8.00      .40      .33   .105+15  .105-11 .112-11   .102-01
   24.00     8.00      .80      .33   .420+15  .722-12 .935-12   .850-02
   24.00     8.00     1.60      .33   .168+16  .161-12 .519-12   .467-02
   24.00    40.00     2.00     1.67   .263+16  .278-13 .295-13   .268-03
   24.00    40.00     4.00     1.67   .105+17  .191-13 .247-13   .225-03
   24.00    40.00     8.00     1.67   .420+17  .426-14 .134-13   .123-03
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Down-current Distribution, BREACH-OF-CONTAINMENT Accident, Batch Release

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RADIONUCLIDE   SN119M
HALF LIFE   .250+03 DAYS
TOTAL RELEASE  .498-02 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .300-08 GRAMS PER CC
MAXIMUM PERMISSIBLE                                       .000       .000

 CURRENT     DOWN  RADIUS     TIME    VOLUME    CONCENTRATION AVE.SPEC.
VELOCITY CURRENT                                  ISO-    AVE.  ACTIVITY
  NM/DAY      NM      NM      DAYS        CC    UCI/CC  UCI/CC    UCI/GM
     .50    1.00     .05      2.00  .164+13  .333-09 .354-09  .118+00
     .50    1.00     .10      2.00  .657+13  .229-09 .296-09  .987-01
     .50    1.00     .20      2.00  .263+14  .510-10 .163-09  .542-01
     .50    8.00     .40     16.00  .105+15  .500-11 .532-11  .177-02
     .50    8.00     .80     16.00  .420+15  .344-11 .445-11  .148-02
     .50    8.00    1.60     16.00  .168+16  .767-12 .295-11  .815-03
     .50   40.00    2.00     80.00  .263+16  .167-12 .178-12  .594-04
     .50   40.00    4.00     80.00  .105+17  .115-12 .149-12  .497-04
     .50   40.00    8.00     80.00  .420+17  .257-13 .819-13  .273-04
    4.00    1.00     .05       .25  .164+13  .334-09 .356-09  .119+00
    4.00    1.00     .10       .25  .657+13  .230-09 .298-09  .992-01
    4.00    1.00     .20       .25  .263+14  .513-10 .164-09  .545-01
    4.00    8.00     .40      2.00  .105+15  .520-11 .553-11  .184-02
    4.00    8.00     .80      2.00  .420+15  .357-11 .463-11  .154-02
    4.00    8.00    1.60      2.00  .168+16  .797-12 .254-11  .848-03
    4.00   40.00    2.00     10.00  .263+16  .203-12 .216-12  .721-04
    4.00   40.00    4.00     10.00  .105+17  .140-12 .181-12  .604-04
    4.00   40.00    8.00     10.00  .420+17  .312-13 .995-13  .332-04
   24.00    1.00     .05       .04  .164+13  .334-09 .356-09  .119+00
   24.00    1.00     .10       .04  .657+13  .230-09 .298-09  .993-01
   24.00    1.00     .20       .04  .263+14  .513-10 .164-09  .545-01
   24.00    8.00     .40       .33  .105+15  .522-11 .555-11  .185-02
   24.00    8.00     .80       .33  .420+15  .359-11 .465-11  .155-02
   24.00    8.00    1.60       .33  .168+16  .801-12 .255-11  .851-03
   24.00   40.00    2.00      1.67  .263+16  .208-12 .221-12  .738-04
   24.00   40.00    4.00      1.67  .105+17  .143-12 .185-12  .618-04
   24.00   40.00    8.00      1.67  .420+17  .319-13 .102-12  .339-04
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RADIONUCLIDE   SN 121
HALF LIFE   .115+01 DAYS
TOTAL RELEASE  .252-02 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .300-08 GRAMS PER CC
MAXIMUM PERMISSIBLE                                       .000       .000

 CURRENT     DOWN  RADIUS     TIME    VOLUME    CONCENTRATION AVE.SPEC.
VELOCITY CURRENT                                  ISO-    AVE.  ACTIVITY
  NM/DAY      NM      NM      DAYS        CC    UCI/CC  UCI/CC    UCI/GM
     .50    1.00     .05      2.00  .164+13  .507-10 .539-10  .180-01
     .50    1.00     .10      2.00  .657+13  .349-10 .452-10  .151-01
     .50    1.00     .20      2.00  .263+14  .774-11 .248-10  .827-02
     .50    8.00     .40     16.00  .105+15  .172-15 .183-15  .609-07
     .50    8.00     .80     16.00  .420+15  .118-15 .153-15  .510-07
     .50    8.00    1.60     16.00  .168+16  .263-16 .840-16  .280-07
     .50   40.00    2.00     80.00  .263+16  .122-33 .130-33  .434-25
     .50   40.00    4.00     80.00  .105+17  .841-34 .109-33  .363-25
     .50   40.00    8.00     80.00  .420+17  .188-34 .599-34  .200-25
    4.00    1.00     .05       .25  .164+13  .146-09 .155-09  .516-01
    4.00    1.00     .10       .25  .657+13  .100-09 .130-09  .432-01
    4.00    1.00     .20       .25  .263+14  .223-10 .712-10  .237-01
    4.00    8.00     .40      2.00  .105+15  .792-12 .843-12  .281-03
    4.00    8.00     .80      2.00  .420+15  .545-12 .706-12  .235-03
    4.00    8.00    1.60      2.00  .168+16  .122-12 .388-12  .129-03
    4.00   40.00    2.00     10.00  .263+16  .255-15 .272-15  .906-07
    4.00   40.00    4.00     10.00  .105+17  .176-15 .227-15  .758-07
    4.00   40.00    8.00     10.00  .420+17  .392-16 .125-15  .417-07
   24.00    1.00     .05       .04  .164+13  .165-09 .176-09  .585-01
   24.00    1.00     .10       .04  .657+13  .113-09 .147-09  .490-01
   24.00    1.00     .20       .04  .263+14  .253-10 .807-10  .269-01
   24.00    8.00     .40       .33  .105+15  .216-11 .230-11  .767-03
   24.00    8.00     .80       .33  .420+15  .149-11 .193-11  .642-03
   24.00    8.00    1.60       .33  .168+16  .332-12 .106-11  .353-03
   24.00   40.00    2.00      1.67  .263+16  .347-13 .412-13  .137-04
   24.00   40.00    4.00      1.67  .105+17  .246-13 .345-13  .115-04
   24.00   40.00    8.00      1.67  .420+17  .594-14 .190-13  .632-05
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Down-current Distribution, BREACH-OF-CONTAINMENT Accident, Batch Release

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RADIONUCLIDE   SN 123
HALF LIFE   .125+03 DAYS
TOTAL RELEASE  .210-03 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .300-08 GRAMS PER CC
MAXIMUM PERMISSIBLE                                    .000        .000

 CURRENT     DOWN   RADIUS      TIME    VOLUME    CONCENTRATION AVE.SPEC.
VELOCITY  CURRENT                                   ISO-    AVE.  ACTIVITY
  NM/DAY       NM       NM      DAYS          CC  UCI/CC  UCI/CC    UCI/GM
     .50     1.00      .05      2.00   .164+13  .139-10 .148-10  .495-02
     .50     1.00      .10      2.00   .657+13  .959-11 .124-10  .414-02
     .50     1.00      .20      2.00   .263+14  .214-11 .682-11  .227-02
     .50     8.00      .40     16.00   .105+15  .202-12 .215-12  .715-04
     .50     8.00      .80     16.00   .420+15  .139-12 .180-12  .599-04
     .50     8.00     1.60     16.00   .168+16  .309-13 .987-13  .329-04
     .50    40.00     2.00     80.00   .263+16  .566-14 .602-14  .201-05
     .50    40.00     4.00     80.00   .105+17  .389-14 .504-14  .168-05
     .50    40.00     8.00     80.00   .420+17  .868-15 .277-14  .923-06
    4.00     1.00      .05       .25   .164+13  .141-10 .150-10  .499-02
    4.00     1.00      .10       .25   .657+13  .968-11 .125-10  .418-02
    4.00     1.00      .20       .25   .263+14  .216-11 .689-11  .230-02
    4.00     8.00      .40      2.00   .105+15  .218-12 .232-12  .773-04
    4.00     8.00      .80      2.00   .420+15  .150-12 .194-12  .647-04
    4.00     8.00     1.60      2.00   .168+16  .334-13 .107-12  .355-04
    4.00    40.00     2.00     10.00   .263+16  .834-14 .887-14  .296-05
    4.00    40.00     4.00     10.00   .105+17  .573-14 .743-14  .248-05
    4.00    40.00     8.00     10.00   .420+17  .128-14 .408-14  .136-05
   24.00     1.00      .05       .04   .164+13  .141-10 .150-10  .500-02
   24.00     1.00      .10       .04   .657+13  .949-11 .126-10  .419-02
   24.00     1.00      .20       .04   .263+14  .216-11 .690-11  .230-02
   24.00     8.00      .40       .33   .105+15  .220-12 .234-12  .780-04
   24.00     8.00      .80       .33   .420+15  .151-12 .196-12  .653-04
   24.00     8.00     1.60       .33   .168+16  .337-13 .108-12  .359-04
   24.00    40.00     2.00      1.67   .263+16  .873-14 .929-14  .310-05
   24.00    40.00     4.00      1.67   .105+17  .600-14 .778-14  .259-05
   24.00    40.00     8.00      1.67   .420+17  .134-14 .427-14  .142-05
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RADIONUCLIDE   SN 125
HALF LIFE   .940+01 DAYS
TOTAL RELEASE  .234-04 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .300-08 GRAMS PER CC
MAXIMUM PERMISSIBLE                                 .320-04     .310+03

 CURRENT     DOWN   RADIUS      TIME    VOLUME    CONCENTRATION AVE.SPEC.
VELOCITY  CURRENT                                   ISO-    AVE.  ACTIVITY
  NM/DAY       NM       NM      DAYS          CC  UCI/CC  UCI/CC    UCI/GM
     .50     1.00      .05      2.00   .164+13  .136-11 .144-11  .481-03
     .50     1.00      .10      2.00   .657+13  .932-12 .121-11  .403-03
     .50     1.00      .20      2.00   .263+14  .208-12 .663-12  .221-03
     .50     8.00      .40     16.00   .105+15  .755-14 .803-14  .268-05
     .50     8.00      .80     16.00   .420+15  .519-14 .672-14  .224-05
     .50     8.00     1.60     16.00   .168+16  .116-14 .369-14  .123-05
     .50    40.00     2.00     80.00   .263+16  .270-17 .287-17  .956-09
     .50    40.00     4.00     80.00   .105+17  .185-17 .240-17  .800-09
     .50    40.00     8.00     80.00   .420+17  .414-18 .132-17  .440-09
    4.00     1.00      .05       .25   .164+13  .154-11 .164-11  .547-03
    4.00     1.00      .10       .25   .657+13  .106-11 .137-11  .458-03
    4.00     1.00      .20       .25   .263+14  .237-12 .755-12  .252-03
    4.00     8.00      .40      2.00   .105+15  .212-13 .225-13  .751-05
    4.00     8.00      .80      2.00   .420+15  .146-13 .189-13  .629-05
    4.00     8.00     1.60      2.00   .168+16  .325-14 .104-13  .346-05
    4.00    40.00     2.00     10.00   .263+16  .470-15 .500-15  .167-06
    4.00    40.00     4.00     10.00   .105+17  .323-15 .418-15  .139-06
    4.00    40.00     8.00     10.00   .420+17  .721-16 .230-15  .766-07
   24.00     1.00      .05       .04   .164+13  .157-11 .167-11  .556-03
   24.00     1.00      .10       .04   .657+13  .108-11 .140-11  .465-03
   24.00     1.00      .20       .04   .263+14  .240-12 .767-12  .256-03
   24.00     8.00      .40       .33   .105+15  .240-13 .255-13  .850-05
   24.00     8.00      .80       .33   .420+15  .165-13 .213-13  .711-05
   24.00     8.00     1.60       .33   .168+16  .367-14 .117-13  .391-05
   24.00    40.00     2.00      1.67   .263+16  .869-15 .924-15  .308-06
   24.00    40.00     4.00      1.67   .105+17  .597-15 .774-15  .258-06
   24.00    40.00     8.00      1.67   .420+17  .133-15 .425-15  .142-06
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Down-current Distribution, BREACH-OF-CONTAINMENT Accident, Batch Release

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RADIONUCLIDE   SB 125
HALF LIFE   .989+03 DAYS
TOTAL RELEASE  .343-02 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .500-09 GRAMS PER CC
MAXIMUM PERMISSIBLE                                  .160-06     .700+02
DAUGHTER OF PREVIOUS RADIONUCLIDE, DECAY FRACTION =  1.0000

 CURRENT    DOWN  RADIUS     TIME    VOLUME   CONCENTRATION AVE.SPEC.
VELOCITY CURRENT                                 ISO-    AVE.  ACTIVITY
  NM/DAY      NM      NM     DAYS        CC   UCI/CC  UCI/CC    UCI/GM
     .50    1.00     .05     2.00  .164+13  .230-09 .245-09   .489+00
     .50    1.00     .10     2.00  .657+13  .154-09 .205-09   .410+00
     .50    1.00     .20     2.00  .263+14  .353-10 .113-09   .225+00
     .50    8.00     .40    16.00  .105+15  .356-11 .379-11   .757-02
     .50    8.00     .80    16.00  .420+15  .245-11 .317-11   .634-02
     .50    8.00    1.60    16.00  .168+16  .546-12 .174-11   .349-02
     .50   40.00    2.00    80.00  .263+16  .136-12 .145-12   .290-03
     .50   40.00    4.00    80.00  .105+17  .936-13 .121-12   .242-03
     .50   40.00    8.00    80.00  .420+17  .209-13 .666-13   .133-03
    4.00    1.00     .05      .25  .164+13  .230-09 .245-09   .490+00
    4.00    1.00     .10      .25  .657+13  .158-09 .205-09   .410+00
    4.00    1.00     .20      .25  .263+14  .353-10 .113-09   .225+00
    4.00    8.00     .40     2.00  .105+15  .359-11 .382-11   .765-02
    4.00    8.00     .80     2.00  .420+15  .247-11 .320-11   .640-02
    4.00    8.00    1.60     2.00  .168+16  .551-12 .176-11   .352-02
    4.00   40.00    2.00    10.00  .263+16  .143-12 .152-12   .304-03
    4.00   40.00    4.00    10.00  .105+17  .983-13 .127-12   .255-03
    4.00   40.00    8.00    10.00  .420+17  .219-13 .699-13   .140-03
   24.00    1.00     .05      .04  .164+13  .230-09 .245-09   .490+00
   24.00    1.00     .10      .04  .657+13  .158-09 .205-09   .410+00
   24.00    1.00     .20      .04  .263+14  .353-10 .113-09   .225+00
   24.00    8.00     .40      .33  .105+15  .360-11 .383-11   .766-02
   24.00    8.00     .80      .33  .420+15  .247-11 .320-11   .641-02
   24.00    8.00    1.60      .33  .168+16  .552-12 .178-11   .352-02
   24.00   40.00    2.00     1.67  .263+16  .144-12 .153-12   .306-03
   24.00   40.00    4.00     1.67  .105+17  .988-13 .128-12   .256-03
   24.00   40.00    8.00     1.67  .420+17  .221-13 .704-13   .141-03
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RADIONUCLIDE   TE125M
HALF LIFE   .580+02 DAYS
TOTAL RELEASE  .230+00 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .000    GRAMS PER CC
MAXIMUM PERMISSIBLE                                  .160-05     .700+00
DAUGHTER OF PREVIOUS RADIONUCLIDE, DECAY FRACTION =   .2200

 CURRENT    DOWN  RADIUS     TIME    VOLUME   CONCENTRATION AVE.SPEC.
VELOCITY CURRENT                                 ISO-    AVE.  ACTIVITY
  NM/DAY      NM      NM     DAYS        CC   UCI/CC  UCI/CC    UCI/GM
     .50    1.00     .05     2.00  .164+13  .151-07 .160-07   .000
     .50    1.00     .10     2.00  .657+13  .104-07 .134-07   .000
     .50    1.00     .20     2.00  .263+14  .231-08 .738-08   .000
     .50    8.00     .40    16.00  .105+15  .199-09 .212-09   .000
     .50    8.00     .80    16.00  .420+15  .137-09 .179-09   .000
     .50    8.00    1.60    16.00  .169+16  .306-10 .976-10   .000
     .50   40.00    2.00    80.00  .263+16  .373-11 .397-11   .000
     .50   40.00    4.00    80.00  .105+17  .256-11 .332-11   .000
     .50   40.00    8.00    80.00  .420+17  .572-12 .183-11   .000
    4.00    1.00     .05      .25  .164+13  .154-07 .164-07   .000
    4.00    1.00     .10      .25  .657+13  .106-07 .137-07   .000
    4.00    1.00     .20      .25  .263+14  .236-08 .753-08   .000
    4.00    8.00     .40     2.00  .105+15  .216-09 .251-09   .000
    4.00    8.00     .80     2.00  .420+15  .162-09 .210-09   .000
    4.00    8.00    1.60     2.00  .168+16  .361-10 .115-09   .000
    4.00   40.00    2.00    10.00  .263+16  .867-11 .912-11   .000
    4.00   40.00    4.00    10.00  .105+17  .584-11 .763-11   .000
    4.00   40.00    8.00    10.00  .420+17  .131-11 .419-11   .000
   24.00    1.00     .05      .04  .164+13  .154-07 .164-07   .000
   24.00    1.00     .10      .04  .657+13  .106-07 .137-07   .000
   24.00    1.00     .20      .04  .263+14  .237-08 .755-08   .000
   24.00    8.00     .40      .33  .105+15  .240-09 .256-09   .000
   24.00    8.00     .80      .33  .420+15  .165-09 .214-09   .000
   24.00    8.00    1.60      .33  .168+16  .369-10 .119-09   .000
   24.00   40.00    2.00     1.67  .263+16  .946-11 .101-10   .000
   24.00   40.00    4.00     1.67  .105+17  .650-11 .843-11   .000
   24.00   40.00    8.00     1.67  .420+17  .145-11 .463-11   .000
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Down-current Distribution, BREACH-OF-CONTAINMENT Accident, Batch Release

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RADIONUCLIDE   SB 126
HALF LIFE    .375+00 DAYS
TOTAL RELEASE   .426-03 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER   .500-09 GRAMS PER CC
MAXIMUM PERMISSIBLE                                   .000         .000

 CURRENT    DOWN   RADIUS     TIME    VOLUME    CONCENTRATION AVE.SPEC.
VELOCITY CURRENT                                  ISO-    AVE.  ACTIVITY
  NM/DAY      NM       NM     DAYS        CC    UCI/CC  UCI/CC    UCI/GM
     .50    1.00      .05     2.00  .164+13  .710-12 .755-12   .151-02
     .50    1.00      .10     2.00  .657+13  .488-12 .632-12   .126-02
     .50    1.00      .20     2.00  .263+14  .109-12 .347-12   .695-03
     .50    8.00      .40    16.00  .105+15  .644-25 .685-25   .137-15
     .50    8.00      .80    16.00  .420+15  .443-25 .574-25   .115-15
     .50    8.00     1.60    16.00  .168+16  .988-26 .315-25   .630-16
     .50   40.00     2.00    80.00  .263+16  .000    .000      .000
     .50   40.00     4.00    80.00  .105+17  .000    .000      .000
     .50   40.00     8.00    80.00  .420+17  .000    .000      .000
    4.00    1.00      .05      .25  .164+13  .160-10 .192-10   .343-01
    4.00    1.00      .10      .25  .657+13  .129-10 .161-10   .321-01
    4.00    1.00      .20      .25  .263+14  .276-11 .882-11   .176-01
    4.00    8.00      .40     2.00  .105+15  .111-13 .118-13   .236-04
    4.00    8.00      .80     2.00  .420+15  .763-14 .988-14   .198-04
    4.00    8.00     1.60     2.00  .168+16  .170-14 .543-14   .109-04
    4.00   40.00     2.00    10.00  .263+16  .169-21 .179-21   .359-12
    4.00   40.00     4.00    10.00  .105+17  .116-21 .150-21   .300-12
    4.00   40.00     8.00    10.00  .420+17  .259-22 .824-22   .145-12
   24.00    1.00      .05      .04  .164+13  .245-10 .282-10   .564-01
   24.00    1.00      .10      .04  .657+13  .182-10 .236-10   .472-01
   24.00    1.00      .20      .04  .263+14  .976-11 .130-10   .259-01
   24.00    8.00      .40      .33  .105+15  .241-12 .257-12   .514-03
   24.00    8.00      .80      .33  .420+15  .166-12 .215-12   .430-03
   24.00    8.00     1.60      .33  .168+16  .370-13 .118-12   .236-03
   24.00   40.00     2.00     1.67  .263+16  .822-15 .874-15   .175-05
   24.00   40.00     4.00     1.67  .105+17  .545-15 .732-15   .146-05
   24.00   40.00     8.00     1.67  .420+17  .126-15 .402-15   .804-06
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RADIONUCLIDE   SB 127
HALF LIFE    .388+01 DAYS
TOTAL RELEASE   .518-01 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER   .500-09 GRAMS PER CC
MAXIMUM PERMISSIBLE                                   .000         .000

 CURRENT    DOWN   RADIUS     TIME    VOLUME    CONCENTRATION AVE.SPEC.
VELOCITY CURRENT                                  ISO-    AVE.  ACTIVITY
  NM/DAY      NM       NM     DAYS        CC    UCI/CC  UCI/CC    UCI/GM
     .50    1.00      .05     2.00  .164+13  .243-08 .259-08   .518+01
     .50    1.00      .10     2.00  .657+13  .167-08 .217-08   .433+01
     .50    1.00      .20     2.00  .263+14  .373-09 .119-08   .238+01
     .50    8.00      .40    16.00  .105+15  .312-11 .332-11   .664-02
     .50    8.00      .80    16.00  .420+15  .214-11 .278-11   .556-02
     .50    8.00     1.60    16.00  .168+16  .478-12 .153-11   .305-02
     .50   40.00     2.00    80.00  .263+16  .135-17 .144-17   .288-08
     .50   40.00     4.00    80.00  .105+17  .931-18 .121-17   .241-08
     .50   40.00     8.00    80.00  .420+17  .208-18 .663-18   .133-08
    4.00    1.00      .05      .25  .164+13  .333-08 .354-08   .708+01
    4.00    1.00      .10      .25  .657+13  .229-08 .296-08   .593+01
    4.00    1.00      .20      .25  .263+14  .510-09 .163-08   .326+01
    4.00    8.00      .40     2.00  .105+15  .380-10 .405-10   .809-01
    4.00    8.00      .80     2.00  .420+15  .261-10 .339-10   .677-01
    4.00    8.00     1.60     2.00  .168+16  .583-11 .186-10   .372-01
    4.00   40.00     2.00    10.00  .263+16  .364-12 .388-12   .775-03
    4.00   40.00     4.00    10.00  .105+17  .250-12 .325-12   .649-03
    4.00   40.00     8.00    10.00  .420+17  .559-13 .178-12   .357-03
   24.00    1.00      .05      .04  .164+13  .345-08 .367-08   .735+01
   24.00    1.00      .10      .04  .657+13  .237-08 .308-08   .615+01
   24.00    1.00      .20      .04  .263+14  .530-09 .169-08   .338+01
   24.00    8.00      .40      .33  .105+15  .512-10 .545-10   .109+00
   24.00    8.00      .80      .33  .420+15  .352-10 .456-10   .912-01
   24.00    8.00     1.60      .33  .168+16  .785-11 .251-10   .501-01
   24.00   40.00     2.00     1.67  .263+16  .161-11 .172-11   .343-02
   24.00   40.00     4.00     1.67  .105+17  .111-11 .144-11   .288-02
   24.00   40.00     8.00     1.67  .420+17  .248-12 .790-12   .158-02
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Down-current Distribution, BREACH-OF-CONTAINMENT Accident, Batch Release

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RADIONUCLIDE   TE127M
HALF LIFE   .109+03 DAYS
TOTAL RELEASE  .935+00 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .000    GRAMS PER CC
MAXIMUM PERMISSIBLE                                   .950-06    .350+00
DAUGHTER OF PREVIOUS RADIONUCLIDE, DECAY FRACTION =   .1400

 CURRENT     DOWN  RADIUS     TIME    VOLUME    CONCENTRATION AVE.SPEC.
VELOCITY CURRENT                                  ISO-    AVE.  ACTIVITY
  NM/DAY      NM      NM     DAYS         CC    UCI/CC  UCI/CC    UCI/GM
     .50    1.00     .05     2.00   .164+13  .620-07 .660-07    .000
     .50    1.00     .10     2.00   .657+13  .426-07 .552-07    .000
     .50    1.00     .20     2.00   .263+14  .951-08 .303-07    .000
     .50    8.00     .40    16.00   .105+15  .887-09 .943-09    .000
     .50    8.00     .80    16.00   .420+15  .609-09 .789-09    .000
     .50    8.00    1.60    16.00   .168+16  .136-09 .434-09    .000
     .50   40.00    2.00    80.00   .263+16  .236-10 .251-10    .000
     .50   40.00    4.00    80.00   .105+17  .162-10 .210-10    .000
     .50   40.00    8.00    80.00   .420+17  .362-11 .115-10    .000
    4.00    1.00     .05      .25   .164+13  .627-07 .667-07    .000
    4.00    1.00     .10      .25   .657+13  .431-07 .558-07    .000
    4.00    1.00     .20      .25   .263+14  .961-08 .307-07    .000
    4.00    8.00     .40     2.00   .105+15  .969-09 .103-08    .000
    4.00    8.00     .80     2.00   .420+15  .666-09 .863-09    .000
    4.00    8.00    1.60     2.00   .168+16  .149-09 .474-09    .000
    4.00   40.00    2.00    10.00   .263+16  .368-10 .392-10    .000
    4.00   40.00    4.00    10.00   .105+17  .253-10 .328-10    .000
    4.00   40.00    8.00    10.00   .420+17  .565-11 .180-10    .000
   24.00    1.00     .05      .04   .164+13  .628-07 .668-07    .000
   24.00    1.00     .10      .04   .657+13  .431-07 .559-07    .000
   24.00    1.00     .20      .04   .263+14  .963-08 .307-07    .000
   24.00    8.00     .40      .33   .105+15  .979-09 .104-08    .000
   24.00    8.00     .80      .33   .420+15  .673-09 .872-09    .000
   24.00    8.00    1.60      .33   .168+16  .150-09 .479-09    .000
   24.00   40.00    2.00     1.67   .263+16  .388-10 .413-10    .000
   24.00   40.00    4.00     1.67   .105+17  .267-10 .346-10    .000
   24.00   40.00    8.00     1.67   .420+17  .596-11 .190-10    .000
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RADIONUCLIDE   TE 127
HALF LIFE   .392+00 DAYS
TOTAL RELEASE  .312+01 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .000    GRAMS PER CC
MAXIMUM PERMISSIBLE                                  .320-05    .230+02
DAUGHTER OF PREVIOUS RADIONUCLIDE, DECAY FRACTION =  1.0000

 CURRENT     DOWN  RADIUS     TIME    VOLUME    CONCENTRATION AVE.SPEC.
VELOCITY CURRENT                                  ISO-    AVE.  ACTIVITY
  NM/DAY      NM      NM     DAYS         CC    UCI/CC  UCI/CC    UCI/GM
     .50    1.00     .05     2.00   .164+13  .687-07 .731-07    .000
     .50    1.00     .10     2.00   .657+13  .472-07 .612-07    .000
     .50    1.00     .20     2.00   .263+14  .105-07 .336-07    .000
     .50    8.00     .40    16.00   .105+15  .893-09 .950-09    .000
     .50    8.00     .80    16.00   .420+15  .613-09 .795-09    .000
     .50    8.00    1.60    16.00   .168+16  .137-09 .437-09    .000
     .50   40.00    2.00    80.00   .263+16  .237-10 .252-10    .000
     .50   40.00    4.00    80.00   .105+17  .163-10 .211-10    .000
     .50   40.00    8.00    80.00   .420+17  .363-11 .116-10    .000
    4.00    1.00     .05      .25   .164+13  .150-06 .168-06    .000
    4.00    1.00     .10      .25   .657+13  .109-06 .141-06    .000
    4.00    1.00     .20      .25   .263+14  .242-07 .774-07    .000
    4.00    8.00     .40     2.00   .105+15  .107-08 .114-08    .000
    4.00    8.00     .80     2.00   .420+15  .738-09 .956-09    .000
    4.00    8.00    1.60     2.00   .168+16  .165-09 .525-09    .000
    4.00   40.00    2.00    10.00   .263+16  .373-10 .397-10    .000
    4.00   40.00    4.00    10.00   .105+17  .256-10 .332-10    .000
    4.00   40.00    8.00    10.00   .420+17  .572-11 .183-10    .000
   24.00    1.00     .05      .04   .164+13  .199-06 .212-06    .000
   24.00    1.00     .10      .04   .657+13  .137-06 .178-06    .000
   24.00    1.00     .20      .04   .263+14  .306-07 .975-07    .000
   24.00    8.00     .40      .33   .105+15  .227-08 .242-08    .000
   24.00    8.00     .80      .33   .420+15  .156-08 .202-08    .000
   24.00    8.00    1.60      .33   .168+16  .348-09 .111-08    .000
   24.00   40.00    2.00     1.67   .263+16  .452-10 .481-10    .000
   24.00   40.00    4.00     1.67   .105+17  .311-10 .402-10    .000
   24.00   40.00    8.00     1.67   .420+17  .693-11 .221-10    .000
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Down-current Distribution, BREACH-OF-CONTAINMENT Accident, Batch Release

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RADIONUCLIDE   TE129M
HALF LIFE   .341+02 DAYS
TOTAL RELEASE  .155+02 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .000    GRAMS PER CC
MAXIMUM PERMISSIBLE                                  .320-06     .180+00

 CURRENT    DOWN   RADIUS     TIME    VOLUME    CONCENTRATION AVE.SPEC.
VELOCITY CURRENT                                   ISO-    AVE.  ACTIVITY
  NM/DAY      NM       NM     DAYS        CC    UCI/CC  UCI/CC    UCI/GM
     .50    1.00      .05     2.00  .164+13  .999-06 .106-05   .000
     .50    1.00      .10     2.00  .657+13  .687-06 .890-06   .000
     .50    1.00      .20     2.00  .263+14  .153-06 .489-06   .000
     .50    8.00      .40    16.00  .105+15  .117-07 .125-07   .000
     .50    8.00      .80    16.00  .420+15  .908-08 .105-07   .000
     .50    8.00     1.60    16.00  .168+16  .180-08 .575-08   .000
     .50   40.00     2.00    80.00  .263+16  .128-09 .136-09   .000
     .50   40.00     4.00    80.00  .105+17  .880-10 .119-09   .000
     .50   40.00     8.00    80.00  .420+17  .196-10 .626-10   .000
    4.00    1.00      .05      .25  .164+13  .104-05 .110-05   .000
    4.00    1.00      .10      .25  .657+13  .712-06 .922-06   .000
    4.00    1.00      .20      .25  .263+14  .159-06 .507-06   .000
    4.00    8.00      .40     2.00  .105+15  .156-07 .166-07   .000
    4.00    8.00      .80     2.00  .420+15  .107-07 .139-07   .000
    4.00    8.00     1.60     2.00  .168+16  .239-08 .764-08   .000
    4.00   40.00     2.00    10.00  .263+16  .531-09 .565-09   .000
    4.00   40.00     4.00    10.00  .105+17  .365-09 .473-09   .000
    4.00   40.00     8.00    10.00  .420+17  .814-10 .240-09   .000
   24.00    1.00      .05      .04  .164+13  .104-05 .111-05   .000
   24.00    1.00      .10      .04  .657+13  .715-06 .926-06   .000
   24.00    1.00      .20      .04  .263+14  .159-06 .509-06   .000
   24.00    8.00      .40      .33  .105+15  .142-07 .172-07   .000
   24.00    8.00      .80      .33  .420+15  .111-07 .144-07   .000
   24.00    8.00     1.60      .33  .168+16  .248-08 .790-08   .000
   24.00   40.00     2.00     1.67  .263+16  .629-09 .669-09   .000
   24.00   40.00     4.00     1.67  .105+17  .432-09 .560-09   .000
   24.00   40.00     8.00     1.67  .420+17  .964-10 .308-09   .000
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RADIONUCLIDE   TE 129
HALF LIFE   .477-01 DAYS
TOTAL RELEASE  .120+02 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .000    GRAMS PER CC
MAXIMUM PERMISSIBLE                                 .130-04     .690+02
DAUGHTER OF PREVIOUS RADIONUCLIDE, DECAY FRACTION =   .6400

 CURRENT    DOWN   RADIUS     TIME    VOLUME    CONCENTRATION AVE.SPEC.
VELOCITY CURRENT                                   ISO-    AVE.  ACTIVITY
  NM/DAY      NM       NM     DAYS        CC    UCI/CC  UCI/CC    UCI/GM
     .50    1.00      .05     2.00  .164+13  .641-06 .681-06   .000
     .50    1.00      .10     2.00  .657+13  .440-06 .570-06   .000
     .50    1.00      .20     2.00  .263+14  .982-07 .313-06   .000
     .50    8.00      .40    16.00  .105+15  .753-08 .801-08   .000
     .50    8.00      .80    16.00  .420+15  .518-08 .671-08   .000
     .50    8.00     1.60    16.00  .168+16  .115-08 .368-08   .000
     .50   40.00     2.00    80.00  .263+14  .820-10 .873-10   .000
     .50   40.00     4.00    80.00  .105+17  .564-10 .731-10   .000
     .50   40.00     8.00    80.00  .420+17  .126-10 .401-10   .000
    4.00    1.00      .05      .25  .164+13  .667-06 .710-06   .000
    4.00    1.00      .10      .25  .657+13  .459-06 .594-06   .000
    4.00    1.00      .20      .25  .263+14  .102-06 .327-06   .000
    4.00    8.00      .40    /2.00  .105+15  .100-07 .106-07   .000
    4.00    8.00      .80     2.00  .420+15  .688-08 .891-08   .000
    4.00    8.00     1.60     2.00  .168+16  .153-08 .490-08   .000
    4.00   40.00     2.00    10.00  .263+16  .340-09 .362-09   .000
    4.00   40.00     4.00    10.00  .105+17  .234-09 .303-09   .000
    4.00   40.00     8.00    10.00  .420+17  .522-10 .166-09   .000
   24.00    1.00      .05      .04  .164+13  .742-06 .790-06   .000
   24.00    1.00      .10      .04  .657+13  .510-06 .661-06   .000
   24.00    1.00      .20      .04  .263+14  .114-06 .363-06   .000
   24.00    8.00      .40      .33  .105+15  .104-07 .110-07   .000
   24.00    8.00      .80      .33  .420+15  .713-08 .924-08   .000
   24.00    8.00     1.60      .33  .168+16  .159-08 .507-08   .000
   24.00   40.00     2.00     1.67  .263+16  .403-09 .429-09   .000
   24.00   40.00     4.00     1.67  .105+17  .277-09 .359-09   .000
   24.00   40.00     8.00     1.67  .420+17  .619-10 .197-09   .000
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Down-current Distribution, BREACH-OF-CONTAINMENT Accident, Batch Release

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RADIONUCLIDE   I 129
HALF LIFE    .620+10 DAYS
TOTAL RELEASE  .349-04 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .600-07 GRAMS PER CC
MAXIMUM PERMISSIBLE                                   .630-09      .750+01
DAUGHTER OF PREVIOUS RADIONUCLIDE, DECAY FRACTION =  1.0000

 CURRENT    DOWN   RADIUS     TIME     VOLUME    CONCENTRATION AVE.SPEC.
VELOCITY CURRENT                                   ISO-    AVE.  ACTIVITY
  NM/DAY      NM       NM     DAYS         CC   UCI/CC  UCI/CC    UCI/GM
     .50    1.00      .05     2.00   .164+13  .234-11 .249-11   .416-09
     .50    1.00      .10     2.00   .657+13  .161-11 .209-11   .348-09
     .50    1.00      .20     2.00   .263+14  .359-12 .115-11   .191-09
     .50    8.00      .40    16.00   .105+15  .366-13 .390-13   .650-06
     .50    8.00      .80    16.00   .420+15  .252-13 .326-13   .544-06
     .50    8.00     1.60    16.00   .168+16  .562-14 .179-13   .299-06
     .50   40.00     2.00    80.00   .263+16  .147-14 .156-14   .260-07
     .50   40.00     4.00    80.00   .105+17  .101-14 .131-14   .218-07
     .50   40.00     8.00    80.00   .420+17  .225-15 .718-15   .120-07
    4.00    1.00      .05      .25   .164+13  .234-11 .249-11   .416-09
    4.00    1.00      .10      .25   .657+13  .161-11 .209-11   .348-09
    4.00    1.00      .20      .25   .263+14  .359-12 .115-11   .191-09
    4.00    8.00      .40     2.00   .105+15  .366-13 .390-13   .649-06
    4.00    8.00      .80     2.00   .420+15  .252-13 .326-13   .544-06
    4.00    8.00     1.60     2.00   .168+16  .562-14 .179-13   .299-06
    4.00   40.00     2.00    10.00   .263+16  .147-14 .156-14   .260-07
    4.00   40.00     4.00    10.00   .105+17  .101-14 .131-14   .218-07
    4.00   40.00     8.00    10.00   .420+17  .225-15 .717-15   .120-07
   24.00    1.00      .05      .04   .164+13  .234-11 .249-11   .416-09
   24.00    1.00      .10      .04   .657+13  .161-11 .209-11   .348-09
   24.00    1.00      .20      .04   .263+14  .359-12 .115-11   .191-09
   24.00    8.00      .40      .33   .105+15  .366-13 .390-13   .649-06
   24.00    8.00      .80      .33   .420+15  .252-13 .326-13   .544-06
   24.00    8.00     1.60      .33   .168+16  .562-14 .179-13   .299-06
   24.00   40.00     2.00     1.67   .263+16  .147-14 .156-14   .260-07
   24.00   40.00     4.00     1.67   .105+17  .101-14 .130-14   .217-07
   24.00   40.00     8.00     1.67   .420+17  .225-15 .717-15   .119-07
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RADIONUCLIDE   TE131M
HALF LIFE    .125+01 DAYS
TOTAL RELEASE  .119+02 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .000    GRAMS PER CC
MAXIMUM PERMISSIBLE                                  .630-06      .220+01

 CURRENT    DOWN   RADIUS     TIME     VOLUME    CONCENTRATION AVE.SPEC.
VELOCITY CURRENT                                   ISO-    AVE.  ACTIVITY
  NM/DAY      NM       NM     DAYS         CC   UCI/CC  UCI/CC    UCI/GM
     .50    1.00      .05     2.00   .164+13  .264-06 .281-06   .000
     .50    1.00      .10     2.00   .657+13  .181-06 .235-06   .000
     .50    1.00      .20     2.00   .263+14  .404-07 .129-06   .000
     .50    8.00      .40    16.00   .105+15  .175-11 .187-11   .000
     .50    8.00      .80    16.00   .420+15  .121-11 .156-11   .000
     .50    8.00     1.60    16.00   .168+16  .269-12 .858-12   .000
     .50   40.00     2.00    80.00   .263+16  .273-28 .291-28   .000
     .50   40.00     4.00    80.00   .105+17  .188-28 .243-28   .000
     .50   40.00     8.00    80.00   .420+17  .419-29 .134-28   .000
    4.00    1.00      .05      .25   .164+13  .696-06 .740-06   .000
    4.00    1.00      .10      .25   .657+13  .478-06 .620-06   .000
    4.00    1.00      .20      .25   .263+14  .107-06 .340-06   .000
    4.00    8.00      .40     2.00   .105+15  .912-08 .438-08   .000
    4.00    8.00      .80     2.00   .420+15  .283-08 .367-08   .000
    4.00    8.00     1.60     2.00   .168+16  .632-09 .202-08   .000
    4.00   40.00     2.00    10.00   .263+16  .175-11 .208-11   .000
    4.00   40.00     4.00    10.00   .105+17  .134-11 .174-11   .000
    4.00   40.00     8.00    10.00   .420+17  .300-12 .956-12   .000
   24.00    1.00      .05      .04   .164+13  .781-06 .831-06   .000
   24.00    1.00      .10      .04   .657+13  .537-06 .695-06   .000
   24.00    1.00      .20      .04   .263+14  .120-06 .382-06   .000
   24.00    8.00      .40      .33   .105+15  .104-07 .110-07   .000
   24.00    8.00      .80      .33   .420+15  .713-08 .924-08   .000
   24.00    8.00     1.60      .33   .168+16  .159-08 .508-08   .000
   24.00   40.00     2.00     1.67   .263+16  .198-09 .211-09   .000
   24.00   40.00     4.00     1.67   .105+17  .136-09 .177-09   .000
   24.00   40.00     8.00     1.67   .420+17  .304-10 .970-10   .000
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Down-current Distribution, BREACH-OF-CONTAINMENT Accident, Batch Release

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RADIONUCLIDE   I 131
HALF LIFE   .805+01 DAYS
TOTAL RELEASE  .152+08 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .600-07 GRAMS PER CC
MAXIMUM PERMISSIBLE                                    .320-08     .320+02
DAUGHTER OF PREVIOUS RADIONUCLIDE, DECAY FRACTION =  1.0000

 CURRENT     DOWN  RADIUS     TIME    VOLUME    CONCENTRATION AVE.SPEC.
VELOCITY CURRENT                                 ISO-    AVE.  ACTIVITY
  NM/DAY      NM      NM     DAYS         CC   UCI/CC  UCI/CC    UCI/GM
     .50    1.00     .05     2.00  .164+13  .859+00 .914+00   .152+08
     .50    1.00     .10     2.00  .657+13  .591+00 .765+00   .128+08
     .50    1.00     .20     2.00  .263+14  .132+00 .420+00   .701+07
     .50    8.00     .40    16.00  .105+15  .402-02 .428-02   .713+05
     .50    8.00     .80    16.00  .420+15  .277-02 .358-02   .597+05
     .50    8.00    1.60    16.00  .168+16  .617-03 .197-02   .328+05
     .50   40.00    2.00    80.00  .263+16  .651-06 .693-06   .115+02
     .50   40.00    4.00    80.00  .105+17  .446-06 .580-06   .967+01
     .50   40.00    8.00    80.00  .420+17  .999-07 .319-06   .531+01
    4.00    1.00     .05      .25  .164+13  .999+00 .106+01   .177+08
    4.00    1.00     .10      .25  .657+13  .687+00 .890+00   .148+08
    4.00    1.00     .20      .25  .263+14  .153+00 .489+00   .815+07
    4.00    8.00     .40     2.00  .105+15  .134-01 .143-01   .238+06
    4.00    8.00     .80     2.00  .420+15  .923-02 .120-01   .199+06
    4.00    8.00    1.60     2.00  .168+16  .206-02 .657-02   .109+06
    4.00   40.00    2.00    10.00  .263+16  .270-03 .287-03   .478+04
    4.00   40.00    4.00    10.00  .105+17  .185-03 .240-03   .400+04
    4.00   40.00    8.00    10.00  .420+17  .414-04 .132-03   .220+04
   24.00    1.00     .05      .04  .164+13  .102+01 .108+01   .180+08
   24.00    1.00     .10      .04  .657+13  .699+00 .906+00   .151+08
   24.00    1.00     .20      .04  .263+14  .156+00 .498+00   .829+07
   24.00    8.00     .40      .33  .105+15  .165-01 .165-01   .275+06
   24.00    8.00     .80      .33  .420+15  .107-01 .138-01   .230+06
   24.00    8.00    1.60      .33  .168+16  .238-02 .758-02   .126+06
   24.00   40.00    2.00     1.67  .263+16  .553-03 .588-03   .980+04
   24.00   40.00    4.00     1.67  .105+17  .380-03 .492-03   .820+04
   24.00   40.00    8.00     1.67  .420+17  .849-04 .270-03   .451+04
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RADIONUCLIDE   XE131M
HALF LIFE   .118+02 DAYS
TOTAL RELEASE  .687+05 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .100-09 GRAMS PER CC
MAXIMUM PERMISSIBLE                                    .000         .000
DAUGHTER OF PREVIOUS RADIONUCLIDE, DECAY FRACTION =   .0060

 CURRENT     DOWN  RADIUS     TIME    VOLUME    CONCENTRATION AVE.SPEC.
VELOCITY CURRENT                                 ISO-    AVE.  ACTIVITY
  NM/DAY      NM      NM     DAYS         CC   UCI/CC  UCI/CC    UCI/GM
     .50    1.00     .05     2.00  .164+13  .472-02 .503-02   .503+08
     .50    1.00     .10     2.00  .657+13  .325-02 .421-02   .421+08
     .50    1.00     .20     2.00  .263+14  .725-03 .231-02   .231+08
     .50    8.00     .40    16.00  .105+15  .566-04 .602-04   .602+06
     .50    8.00     .80    16.00  .420+15  .389-04 .504-04   .504+06
     .50    8.00    1.60    16.00  .168+16  .868-05 .277-04   .277+06
     .50   40.00    2.00    80.00  .263+16  .927-07 .987-07   .987+03
     .50   40.00    4.00    80.00  .105+17  .637-07 .826-07   .826+03
     .50   40.00    8.00    80.00  .420+17  .142-07 .454-07   .454+03
    4.00    1.00     .05      .25  .164+13  .463-02 .493-02   .493+08
    4.00    1.00     .10      .25  .657+13  .319-02 .413-02   .413+08
    4.00    1.00     .20      .25  .263+14  .711-03 .227-02   .227+08
    4.00    8.00     .40     2.00  .105+15  .738-04 .785-04   .785+06
    4.00    8.00     .80     2.00  .420+15  .507-04 .657-04   .657+06
    4.00    8.00    1.60     2.00  .168+16  .113-04 .361-04   .361+06
    4.00   40.00    2.00    10.00  .263+16  .270-05 .287-05   .287+05
    4.00   40.00    4.00    10.00  .105+17  .185-05 .240-05   .240+05
    4.00   40.00    8.00    10.00  .420+17  .413-06 .132-05   .132+05
   24.00    1.00     .05      .04  .164+13  .462-02 .491-02   .491+08
   24.00    1.00     .10      .04  .657+13  .317-02 .411-02   .411+08
   24.00    1.00     .20      .04  .263+14  .708-03 .226-02   .226+08
   24.00    8.00     .40      .33  .105+15  .725-04 .771-04   .771+06
   24.00    8.00     .80      .33  .420+15  .498-04 .646-04   .646+06
   24.00    8.00    1.60      .33  .168+16  .111-04 .355-04   .355+06
   24.00   40.00    2.00     1.67  .263+16  .295-05 .313-05   .313+05
   24.00   40.00    4.00     1.67  .105+17  .203-05 .262-05   .262+05
   24.00   40.00    8.00     1.67  .420+17  .452-06 .144-05   .144+05
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Down-current Distribution, BREACH-OF-CONTAINMENT Accident, Batch Release

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RADIONUCLIDE   TE 132
HALF LIFE   .324+01 DAYS
TOTAL RELEASE  .157+03 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .000    GRAMS PER CC
MAXIMUM PERMISSIBLE
                                                  .320-06     .730+00

 CURRENT     DOWN   RADIUS     TIME    VOLUME    CONCENTRATION AVE.SPEC.
VELOCITY CURRENT                                     ISO-    AVE.  ACTIVITY
  NM/DAY      NM        NM     DAYS          CC   UCI/CC  UCI/CC    UCI/GM
     .50    1.00       .05     2.00     .164+13  .687-05 .731-05     .000
     .50    1.00       .10     2.00     .657+13  .472-05 .612-05     .000
     .50    1.00       .20     2.00     .263+14  .105-05 .336-05     .000
     .50    8.00       .40    16.00     .105+15  .538-08 .572-08     .000
     .50    8.00       .80    16.00     .420+15  .370-08 .479-08     .000
     .50    8.00      1.60    16.00     .168+16  .825-09 .263-08     .000
     .50   40.00      2.00    80.00     .263+16  .244-15 .260-15     .000
     .50   40.00      4.00    80.00     .105+17  .168-15 .217-15     .000
     .50   40.00      8.00    80.00     .420+17  .374-16 .119-15     .000
    4.00    1.00       .05      .25     .164+13  .999-05 .106-04     .000
    4.00    1.00       .10      .25     .657+13  .687-05 .890-05     .000
    4.00    1.00       .20      .25     .263+14  .153-05 .489-05     .000
    4.00    8.00       .40     2.00     .105+15  .107-06 .114-06     .000
    4.00    8.00       .80     2.00     .420+15  .738-07 .957-07     .000
    4.00    8.00      1.60     2.00     .168+16  .165-07 .525-07     .000
    4.00   40.00      2.00    10.00     .263+16  .776-09 .826-09     .000
    4.00   40.00      4.00    10.00     .105+17  .533-09 .691-09     .000
    4.00   40.00      8.00    10.00     .420+17  .119-09 .380-09     .000
   24.00    1.00       .05      .04     .164+13  .105-04 .111-04     .000
   24.00    1.00       .10      .04     .657+13  .718-05 .931-05     .000
   24.00    1.00       .20      .04     .263+14  .140-05 .511-05     .000
   24.00    8.00       .40      .33     .105+15  .153-06 .163-06     .000
   24.00    8.00       .80      .33     .420+15  .105-06 .137-06     .000
   24.00    8.00      1.60      .33     .168+16  .235-07 .751-07     .000
   24.00   40.00      2.00     1.67     .263+16  .461-08 .491-08     .000
   24.00   40.00      4.00     1.67     .105+17  .317-08 .411-08     .000
   24.00   40.00      8.00     1.67     .420+17  .708-09 .226-08     .000
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RADIONUCLIDE   I 132
HALF LIFE   .942-01 DAYS
TOTAL RELEASE  .397+07 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .600-07 GRAMS PER CC
MAXIMUM PERMISSIBLE
                                                  .000         .110+04
DAUGHTER OF PREVIOUS RADIONUCLIDE, DECAY FRACTION =  1.0000

 CURRENT     DOWN   RADIUS     TIME    VOLUME    CONCENTRATION AVE.SPEC.
VELOCITY CURRENT                                     ISO-    AVE.  ACTIVITY
  NM/DAY      NM        NM     DAYS          CC   UCI/CC  UCI/CC    UCI/GM
     .50    1.00       .05     2.00     .164+13  .719-05 .765-05   .127+03
     .50    1.00       .10     2.00     .657+13  .494-05 .640-05   .107+03
     .50    1.00       .20     2.00     .263+14  .110-05 .352-05   .586+02
     .50    8.00       .40    16.00     .105+15  .554-08 .589-08   .982-01
     .50    8.00       .80    16.00     .420+15  .381-08 .493-08   .822-01
     .50    8.00      1.60    16.00     .168+16  .849-09 .271-08   .452-01
     .50   40.00      2.00    80.00     .263+16  .251-15 .267-15   .446-08
     .50   40.00      4.00    80.00     .105+17  .173-15 .224-15   .373-08
     .50   40.00      8.00    80.00     .420+17  .386-16 .123-15   .205-08
    4.00    1.00       .05      .25     .164+13  .424-01 .451-01   .752+06
    4.00    1.00       .10      .25     .657+13  .291-01 .377-01   .629+06
    4.00    1.00       .20      .25     .263+14  .650-02 .207-01   .346+06
    4.00    9.00       .40     2.00     .105+15  .112-06 .119-06   .199+01
    4.00    8.00       .80     2.00     .420+15  .772-07 .100-06   .167+01
    4.00    8.00      1.60     2.00     .168+16  .172-07 .550-07   .916+00
    4.00   40.00      2.00    10.00     .263+16  .799-09 .850-09   .142-01
    4.00   40.00      4.00    10.00     .105+17  .549-09 .712-09   .119-01
    4.00   40.00      8.00    10.00     .420+17  .123-09 .391-09   .652-02
   24.00    1.00       .05      .04     .164+13  .196+00 .209+00   .348+07
   24.00    1.00       .10      .04     .657+13  .135+00 .175+00   .291+07
   24.00    1.00       .20      .04     .263+14  .301-01 .960-01   .163+07
   24.00    8.00       .40      .33     .105+15  .359-03 .382-03   .636+04
   24.00    8.00       .80      .33     .420+15  .247-03 .320-03   .533+04
   24.00    8.00      1.60      .33     .168+16  .550-04 .176-03   .293+04
   24.00   40.00      2.00     1.67     .263+16  .554-08 .589-08   .982-01
   24.00   40.00      4.00     1.67     .105+17  .381-08 .493-08   .822-01
   24.00   40.00      8.00     1.67     .420+17  .850-09 .271-08   .452-01
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Down-current Distribution, BREACH-OF-CONTAINMENT Accident, Batch Release

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RADIONUCLIDE   I 133
HALF LIFE   .846+00 DAYS
TOTAL RELEASE  .153+08 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .600-07 GRAMS PER CC
MAXIMUM PERMISSIBLE                                  .110-07     .120+03

 CURRENT     DOWN  RADIUS     TIME    VOLUME    CONCENTRATION AVE.SPEC.
VELOCITY  CURRENT                                  ISO-    AVE.  ACTIVITY
  NM/DAY       NM      NM     DAYS         CC    UCI/CC  UCI/CC    UCI/GM
     .50     1.00     .05     2.00   .164+13   .200+00 .212+00   .354+07
     .50     1.00     .10     2.00   .657+13   .137+00 .178+00   .296+07
     .50     1.00     .20     2.00   .263+14   .306-01 .977-01   .163+07
     .50     8.00     .40    16.00   .105+15   .326-07 .347-07   .578+00
     .50     8.00     .80    16.00   .420+15   .224-07 .291-07   .484+00
     .50     8.00    1.60    16.00   .168+16   .500-08 .160-07   .266+00
     .50    40.00    2.00    80.00   .263+16   .223-31 .237-31   .395-29
     .50    40.00    4.00    80.00   .105+17   .153-31 .198-31   .330-29
     .50    40.00    8.00    80.00   .420+17   .341-32 .109-31   .182-29
    4.00     1.00     .05      .25   .164+13   .837+00 .891+00   .148+08
    4.00     1.00     .10      .25   .657+13   .575+00 .746+00   .124+08
    4.00     1.00     .20      .25   .263+14   .128+00 .410+00   .683+07
    4.00     8.00     .40     2.00   .105+15   .312-02 .332-02   .553+05
    4.00     8.00     .80     2.00   .420+15   .214-02 .278-02   .463+05
    4.00     8.00    1.60     2.00   .168+16   .478-03 .153-02   .254+05
    4.00    40.00    2.00    10.00   .263+16   .178-06 .189-06   .315+01
    4.00    40.00    4.00    10.00   .105+17   .122-06 .158-06   .264+01
    4.00    40.00    8.00    10.00   .420+17   .273-07 .870-07   .145+01
   24.00     1.00     .05      .04   .164+13   .993+00 .106+01   .176+08
   24.00     1.00     .10      .04   .657+13   .683+00 .884+00   .147+08
   24.00     1.00     .20      .04   .263+14   .152+00 .486+00   .810+07
   24.00     8.00     .40      .33   .105+15   .122-01 .130-01   .217+06
   24.00     8.00     .80      .33   .420+15   .840-02 .109-01   .181+06
   24.00     8.00    1.60      .33   .168+16   .187-02 .598-02   .996+05
   24.00    40.00    2.00     1.67   .263+16   .164-03 .174-03   .291+04
   24.00    40.00    4.00     1.67   .105+17   .113-03 .146-03   .243+04
   24.00    40.00    8.00     1.67   .420+17   .251-04 .802-04   .134+04
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RADIONUCLIDE   XE133M
HALF LIFE   .226+01 DAYS
TOTAL RELEASE  .322+07 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .100-09 GRAMS PER CC
MAXIMUM PERMISSIBLE                                  .000        .000
DAUGHTER OF PREVIOUS RADIONUCLIDE, DECAY FRACTION =  1.0000

 CURRENT     DOWN  RADIUS     TIME    VOLUME    CONCENTRATION AVE.SPEC.
VELOCITY  CURRENT                                  ISO-    AVE.  ACTIVITY
  NM/DAY       NM      NM     DAYS         CC    UCI/CC  UCI/CC    UCI/GM
     .50     1.00     .05     2.00   .164+13   .331+00 .352+00   .352+10
     .50     1.00     .10     2.00   .657+13   .227+00 .294+00   .294+10
     .50     1.00     .20     2.00   .263+14   .507-01 .162+00   .162+10
     .50     8.00     .40    16.00   .105+15   .961-04 .102-03   .102+07
     .50     8.00     .80    16.00   .420+15   .660-04 .856-04   .856+06
     .50     8.00    1.60    16.00   .168+16   .147-04 .470-04   .470+06
     .50    40.00    2.00    80.00   .263+16   .115-13 .123-13   .123-03
     .50    40.00    4.00    80.00   .105+17   .792-14 .103-13   .103-03
     .50    40.00    8.00    80.00   .420+17   .177-14 .564-14   .564-04
    4.00     1.00     .05      .25   .164+13   .269+00 .286+00   .286+10
    4.00     1.00     .10      .25   .657+13   .185+00 .239+00   .239+10
    4.00     1.00     .20      .25   .263+14   .412-01 .131+00   .131+10
    4.00     8.00     .40     2.00   .105+15   .517-02 .550-02   .550+08
    4.00     8.00     .80     2.00   .420+15   .356-02 .460-02   .460+08
    4.00     8.00    1.60     2.00   .168+16   .792-03 .253-02   .253+08
    4.00    40.00    2.00    10.00   .263+16   .241-04 .256-04   .256+06
    4.00    40.00    4.00    10.00   .105+17   .166-04 .215-04   .215+06
    4.00    40.00    8.00    10.00   .420+17   .369-05 .118-04   .118+06
   24.00     1.00     .05      .04   .164+13   .226+00 .241+00   .241+10
   24.00     1.00     .10      .04   .657+13   .156+00 .202+00   .202+10
   24.00     1.00     .20      .04   .263+14   .347-01 .111+00   .111+10
   24.00     8.00     .40      .33   .105+15   .441-02 .469-02   .469+08
   24.00     8.00     .80      .33   .420+15   .303-02 .393-02   .393+08
   24.00     8.00    1.60      .33   .168+16   .677-03 .216-02   .216+08
   24.00    40.00    2.00     1.67   .263+16   .213-03 .227-03   .227+07
   24.00    40.00    4.00     1.67   .105+17   .147-03 .190-03   .190+07
   24.00    40.00    8.00     1.67   .420+17   .327-04 .104-03   .104+07
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Down-current Distribution, BREACH-OF-CONTAINMENT Accident, Batch Release

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RADIONUCLIDE   XE 133
HALF LIFE   .527+01 DAYS
TOTAL RELEASE  .200+08 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .100-09 GRAMS PER CC
MAXIMUM PERMISSIBLE                                   .000         .000
DAUGHTER OF PREVIOUS RADIONUCLIDE, DECAY FRACTION =  1.0000

 CURRENT    DOWN  RADIUS    TIME   VOLUME   CONCENTRATION AVE.SPEC.
VELOCITY CURRENT                             ISO-    AVE.  ACTIVITY
  NM/DAY      NM      NM    DAYS       CC  UCI/CC  UCI/CC    UCI/GM
     .50    1.00     .05    2.00  .164+13 .111+01 .118+01   .118+11
     .50    1.00     .10    2.00  .657+13 .761+00 .986+00   .986+10
     .50    1.00     .20    2.00  .263+14 .170+00 .541+00   .541+10
     .50    8.00     .40   16.00  .105+15 .345-02 .367-02   .367+08
     .50    8.00     .80   16.00  .420+15 .237-02 .307-02   .307+08
     .50    8.00    1.60   16.00  .168+16 .529-03 .169-02   .169+08
     .50   40.00    2.00   80.00  .263+16 .312-07 .332-07   .332+03
     .50   40.00    4.00   80.00  .105+17 .214-07 .278-07   .278+03
     .50   40.00    8.00   80.00  .420+17 .479-08 .153-07   .153+03
    4.00    1.00     .05     .25  .164+13 .131+01 .139+01   .139+11
    4.00    1.00     .10     .25  .657+13 .899+00 .116+01   .116+11
    4.00    1.00     .20     .25  .263+14 .201+00 .640+00   .640+10
    4.00    8.00     .40    2.00  .105+15 .173-01 .184-01   .184+09
    4.00    8.00     .80    2.00  .420+15 .119-01 .154-01   .154+09
    4.00    8.00    1.60    2.00  .168+16 .265-02 .846-02   .846+08
    4.00   40.00    2.00   10.00  .263+16 .292-03 .311-03   .311+07
    4.00   40.00    4.00   10.00  .105+17 .201-03 .260-03   .260+07
    4.00   40.00    8.00   10.00  .420+17 .448-04 .143-03   .143+07
   24.00    1.00     .05     .04  .164+13 .134+01 .142+01   .142+11
   24.00    1.00     .10     .04  .657+13 .919+00 .119+01   .119+11
   24.00    1.00     .20     .04  .263+14 .205+00 .654+00   .654+10
   24.00    8.00     .40     .33  .105+15 .203-01 .215-01   .215+09
   24.00    8.00     .80     .33  .420+15 .139-01 .180-01   .180+09
   24.00    8.00    1.60     .33  .168+16 .311-02 .991-02   .991+08
   24.00   40.00    2.00    1.67  .263+16 .713-03 .759-03   .759+07
   24.00   40.00    4.00    1.67  .105+17 .490-03 .635-03   .635+07
   24.00   40.00    8.00    1.67  .420+17 .109-03 .349-03   .349+07
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RADIONUCLIDE   TE 134
HALF LIFE   .292-01 DAYS
TOTAL RELEASE  .103+02 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .000    GRAMS PER CC
MAXIMUM PERMISSIBLE                                  .000         .000

 CURRENT    DOWN  RADIUS    TIME   VOLUME   CONCENTRATION AVE.SPEC.
VELOCITY CURRENT                             ISO-    AVE.  ACTIVITY
  NM/DAY      NM      NM    DAYS       CC  UCI/CC  UCI/CC    UCI/GM
     .50    1.00     .05    2.00  .164+13 .168-26 .179-26   .000
     .50    1.00     .10    2.00  .657+13 .116-26 .150-26   .000
     .50    1.00     .20    2.00  .263+14 .258-27 .823-27   .000
     .50    8.00     .40   16.00  .105+15 .000    .000      .000
     .50    8.00     .80   16.00  .420+15 .000    .000      .000
     .50    8.00    1.60   16.00  .168+16 .000    .000      .000
     .50   40.00    2.00   80.00  .263+16 .000    .000      .000
     .50   40.00    4.00   80.00  .105+17 .000    .000      .000
     .50   40.00    8.00   80.00  .420+17 .000    .000      .000
    4.00    1.00     .05     .25  .164+13 .183-08 .195-08   .000
    4.00    1.00     .10     .25  .657+13 .126-08 .163-08   .000
    4.00    1.00     .20     .25  .263+14 .281-09 .897-09   .000
    4.00    8.00     .40    2.00  .105+15 .263-28 .280-28   .000
    4.00    8.00     .80    2.00  .420+15 .181-28 .234-28   .000
    4.00    8.00    1.60    2.00  .168+16 .403-29 .129-28   .000
    4.00   40.00    2.00   10.00  .263+16 .000    .000      .000
    4.00   40.00    4.00   10.00  .105+17 .000    .000      .000
    4.00   40.00    8.00   10.00  .420+17 .000    .000      .000
   24.00    1.00     .05     .04  .164+13 .257-06 .274-06   .000
   24.00    1.00     .10     .04  .657+13 .177-06 .229-06   .000
   24.00    1.00     .20     .04  .263+14 .395-07 .126-06   .000
   24.00    8.00     .40     .33  .105+15 .396-11 .422-11   .000
   24.00    8.00     .80     .33  .420+15 .272-11 .353-11   .000
   24.00    8.00    1.60     .33  .168+16 .608-12 .199-11   .000
   24.00   40.00    2.00    1.67  .263+16 .287-26 .305-26   .000
   24.00   40.00    4.00    1.67  .105+17 .197-26 .255-26   .000
   24.00   40.00    8.00    1.67  .420+17 .440-27 .140-26   .000
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Down-current Distribution, BREACH-OF-CONTAINMENT Accident, Batch Release

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RADIONUCLIDE   I 134
HALF LIFE    .361-01 DAYS
TOTAL RELEASE  .445+07 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .600-07 GRAMS PER CC
MAXIMUM PERMISSIBLE                                       .160-06     .190+04
DAUGHTER OF PREVIOUS RADIONUCLIDE, DECAY FRACTION =  1.0000

 CURRENT    DOWN  RADIUS     TIME   VOLUME   CONCENTRATION AVE.SPEC.
VELOCITY CURRENT                               ISO-    AVE.  ACTIVITY
  NM/DAY      NM      NM     DAYS       CC   UCI/CC  UCI/CC    UCI/GM
     .50    1.00     .05     2.00  .164+13  .633-17 .673-17   .112-09
     .50    1.00     .10     2.00  .657+13  .435-17 .564-17   .940-10
     .50    1.00     .20     2.00  .263+14  .971-18 .310-17   .516-10
     .50    8.00     .40    16.00  .105+15  .000    .000      .000
     .50    8.00     .80    16.00  .420+15  .000    .000      .000
     .50    8.00    1.60    16.00  .168+16  .000    .000      .000
     .50   40.00    2.00    80.00  .263+16  .000    .000      .000
     .50   40.00    4.00    80.00  .105+17  .000    .000      .000
     .50   40.00    8.00    80.00  .420+17  .000    .000      .000
    4.00    1.00     .05      .25  .164+13  .246-02 .262-02   .436+05
    4.00    1.00     .10      .25  .657+13  .169-02 .219-02   .365+05
    4.00    1.00     .20      .25  .263+14  .377-03 .120-02   .201+05
    4.00    8.00     .40     2.00  .105+15  .489-19 .105-18   .175-11
    4.00    8.00     .80     2.00  .420+15  .680-19 .881-19   .147-11
    4.00    8.00    1.60     2.00  .168+16  .152-19 .484-19   .807-12
    4.00   40.00    2.00    10.00  .263+16  .000    .000      .000
    4.00   40.00    4.00    10.00  .105+17  .000    .000      .000
    4.00   40.00    8.00    10.00  .420+17  .000    .000      .000
   24.00    1.00     .05      .04  .164+13  .134+00 .143+00   .238+07
   24.00    1.00     .10      .04  .657+13  .923-01 .120+00   .199+07
   24.00    1.00     .20      .04  .263+14  .206-01 .657-01   .110+07
   24.00    8.00     .40      .33  .105+15  .777-05 .826-05   .138+03
   24.00    8.00     .80      .33  .420+15  .534-05 .692-05   .115+03
   24.00    8.00    1.60      .33  .168+16  .119-05 .380-05   .633+02
   24.00   40.00    2.00     1.67  .263+16  .238-17 .253-17   .422-10
   24.00   40.00    4.00     1.67  .105+17  .163-17 .212-17   .353-10
   24.00   40.00    8.00     1.67  .420+17  .365-18 .116-17   .194-10
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RADIONUCLIDE   CS 134
HALF LIFE    .748+03 DAYS
TOTAL RELEASE  .172+04 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .380-03 GRAMS PER CC
MAXIMUM PERMISSIBLE                                   .900-06     .150-01

 CURRENT    DOWN  RADIUS     TIME   VOLUME   CONCENTRATION AVE.SPEC.
VELOCITY CURRENT                               ISO-    AVE.  ACTIVITY
  NM/DAY      NM      NM     DAYS       CC   UCI/CC  UCI/CC    UCI/GM
     .50    1.00     .05     2.00  .164+13  .115-03 .123-03   .323+00
     .50    1.00     .10     2.00  .657+13  .792-04 .103-03   .270+00
     .50    1.00     .20     2.00  .263+14  .177-04 .564-04   .148+00
     .50    8.00     .40    16.00  .105+15  .178-05 .189-05   .498-02
     .50    8.00     .80    16.00  .420+15  .122-05 .158-05   .417-02
     .50    8.00    1.60    16.00  .168+16  .273-06 .870-06   .229-02
     .50   40.00    2.00    80.00  .263+16  .670-07 .713-07   .188-03
     .50   40.00    4.00    80.00  .105+17  .461-07 .597-07   .157-03
     .50   40.00    8.00    80.00  .420+17  .103-07 .328-07   .863-04
    4.00    1.00     .05      .25  .164+13  .115-03 .123-03   .323+00
    4.00    1.00     .10      .25  .657+13  .794-04 .103-03   .271+00
    4.00    1.00     .20      .25  .263+14  .177-04 .565-04   .149+00
    4.00    8.00     .40     2.00  .105+15  .180-05 .192-05   .504-02
    4.00    8.00     .80     2.00  .420+15  .124-05 .160-05   .422-02
    4.00    8.00    1.60     2.00  .168+16  .276-06 .861-06   .232-02
    4.00   40.00    2.00    10.00  .263+16  .715-07 .761-07   .200-03
    4.00   40.00    4.00    10.00  .105+17  .492-07 .637-07   .169-03
    4.00   40.00    8.00    10.00  .420+17  .110-07 .350-07   .921-04
   24.00    1.00     .05      .04  .164+13  .116-03 .123-03   .323+00
   24.00    1.00     .10      .04  .657+13  .794-04 .103-03   .271+00
   24.00    1.00     .20      .04  .263+14  .177-04 .565-04   .149+00
   24.00    8.00     .40      .33  .105+15  .180-05 .192-05   .505-02
   24.00    8.00     .80      .33  .420+15  .129-05 .141-05   .423-02
   24.00    8.00    1.60      .33  .168+16  .277-06 .883-06   .232-02
   24.00   40.00    2.00     1.67  .263+16  .721-07 .767-07   .202-03
   24.00   40.00    4.00     1.67  .105+17  .495-07 .642-07   .169-03
   24.00   40.00    8.00     1.67  .420+17  .111-07 .353-07   .928-04
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Down-current Distribution, BREACH-OF-CONTAINMENT Accident, Batch Release

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RADIONUCLIDE   I 135
HALF LIFE   .274+00 DAYS
TOTAL RELEASE  .931+07 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .600-07 GRAMS PER CC
MAXIMUM PERMISSIBLE                                   .320-07     .370+03

 CURRENT     DOWN  RADIUS     TIME    VOLUME    CONCENTRATION AVE.SPEC.
VELOCITY  CURRENT                                  ISO-    AVE.  ACTIVITY
  NM/DAY       KM      KM     DAYS        CC    UCI/CC  UCI/CC    UCI/GM
     .50     1.00     .05     2.00   .164+13   .427-02 .455-02   .758+05
     .50     1.00     .10     2.00   .657+13   .294-02 .381-02   .634+05
     .50     1.00     .20     2.00   .263+14   .655-03 .209-02   .349+05
     .50     8.00     .40    16.00   .105+15   .466-19 .495-19   .826-12
     .50     8.00     .80    16.00   .420+15   .320-19 .415-19   .691-12
     .50     8.00    1.60    16.00   .168+16   .714-20 .228-19   .380-12
     .50    40.00    2.00    80.00   .263+16   .000    .000      .000
     .50    40.00    4.00    80.00   .105+17   .000    .000      .000
     .50    40.00    8.00    80.00   .420+17   .000    .000      .000
    4.00     1.00     .05      .25   .164+13   .335+00 .357+00   .594+07
    4.00     1.00     .10      .25   .657+13   .230+00 .299+00   .498+07
    4.00     1.00     .20      .25   .263+14   .514-01 .164+00   .273+07
    4.00     8.00     .40     2.00   .105+15   .668-04 .710-04   .118+04
    4.00     8.00     .80     2.00   .420+15   .459-04 .595-04   .991+03
    4.00     8.00    1.60     2.00   .168+16   .192-04 .327-04   .545+03
    4.00    40.00    2.00    10.00   .263+16   .583-14 .620-14   .103-06
    4.00    40.00    4.00    10.00   .105+17   .491-14 .519-14   .866-07
    4.00    40.00    8.00    10.00   .420+17   .894-15 .285-14   .476-07
   24.00     1.00     .05      .04   .164+13   .564+00 .600+00   .999+07
   24.00     1.00     .10      .04   .657+13   .387+00 .502+00   .836+07
   24.00     1.00     .20      .04   .263+14   .864-01 .276+00   .460+07
   24.00     8.00     .40      .33   .105+15   .426-02 .453-02   .755+05
   24.00     8.00     .80      .33   .420+15   .293-02 .379-02   .632+05
   24.00     8.00    1.60      .33   .168+16   .653-03 .208-02   .347+05
   24.00    40.00    2.00     1.67   .263+16   .613-05 .652-05   .109+03
   24.00    40.00    4.00     1.67   .105+17   .421-05 .546-05   .910+02
   24.00    40.00    8.00     1.67   .420+17   .940-06 .300-05   .500+02
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RADIONUCLIDE   XE135M
HALF LIFE   .108-01 DAYS
TOTAL RELEASE  .297+06 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .100-09 GRAMS PER CC
MAXIMUM PERMISSIBLE                                   .000        .000
DAUGHTER OF PREVIOUS RADIONUCLIDE, DECAY FRACTION =   .2700

 CURRENT     DOWN  RADIUS     TIME    VOLUME    CONCENTRATION AVE.SPEC.
VELOCITY  CURRENT                                  ISO-    AVE.  ACTIVITY
  NM/DAY       KM      KM     DAYS        CC    UCI/CC  UCI/CC    UCI/GM
     .50     1.00     .05     2.00   .164+13   .120-02 .124-02   .128+08
     .50     1.00     .10     2.00   .657+13   .825-03 .107-02   .107+08
     .50     1.00     .20     2.00   .263+14   .184-03 .587-03   .587+07
     .50     8.00     .40    16.00   .105+15   .131-19 .139-19   .139-09
     .50     8.00     .80    16.00   .420+15   .899-20 .116-19   .116-09
     .50     8.00    1.60    16.00   .168+16   .201-20 .640-20   .640-10
     .50    40.00    2.00    80.00   .263+16   .000    .000      .000
     .50    40.00    4.00    80.00   .105+17   .000    .000      .000
     .50    40.00    8.00    80.00   .420+17   .000    .000      .000
    4.00     1.00     .05      .25   .164+13   .942-01 .100+00   .100+10
    4.00     1.00     .10      .25   .657+13   .647-01 .839-01   .839+09
    4.00     1.00     .20      .25   .263+14   .144-01 .461-01   .461+09
    4.00     8.00     .40     2.00   .105+15   .188-04 .200-04   .200+06
    4.00     8.00     .80     2.00   .420+15   .129-04 .167-04   .167+06
    4.00     8.00    1.60     2.00   .168+16   .288-05 .918-05   .918+05
    4.00    40.00    2.00    10.00   .263+16   .144-14 .174-14   .174-04
    4.00    40.00    4.00    10.00   .105+17   .113-14 .146-14   .146-04
    4.00    40.00    8.00    10.00   .420+17   .251-15 .802-15   .802-05
   24.00     1.00     .05      .04   .164+13   .148+00 .157+00   .157+10
   24.00     1.00     .10      .04   .657+13   .101+00 .131+00   .131+10
   24.00     1.00     .20      .04   .263+14   .226-01 .722-01   .722+09
   24.00     8.00     .40      .33   .105+15   .120-02 .127-02   .127+08
   24.00     8.00     .80      .33   .420+15   .822-03 .106-02   .106+08
   24.00     8.00    1.60      .33   .168+16   .183-03 .585-03   .585+07
   24.00    40.00    2.00     1.67   .263+16   .172-05 .183-05   .183+05
   24.00    40.00    4.00     1.67   .105+17   .118-05 .153-05   .153+05
   24.00    40.00    8.00     1.67   .420+17   .264-06 .843-06   .843+04
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Down-current Distribution, BREACH-OF-CONTAINMENT Accident, Batch Release

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RADIONUCLIDE   XE 135
HALF LIFE   .381+00 DAYS
TOTAL RELEASE  .586+07 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .100-09 GRAMS PER CC
MAXIMUM PERMISSIBLE                                  .000        .000
DAUGHTER OF PREVIOUS RADIONUCLIDE, DECAY FRACTION =  1.0000

 CURRENT    DOWN  RADIUS    TIME    VOLUME    CONCENTRATION AVE.SPEC.
VELOCITY CURRENT                               ISO-    AVE.  ACTIVITY
  NM/DAY      KM      KM    DAYS        CC   UCI/CC  UCI/CC    UCI/GM
     .50    1.00     .05    2.00  .164+13  .435-01 .462-01   .462+09
     .50    1.00     .10    2.00  .657+13  .299-01 .387-01   .387+09
     .50    1.00     .20    2.00  .263+14  .666-02 .213-01   .213+09
     .50    8.00     .40   16.00  .105+15  .752-14 .800-14   .800-04
     .50    8.00     .80   16.00  .420+15  .517-14 .669-14   .669-04
     .50    8.00    1.60   16.00  .168+16  .115-14 .369-14   .369-04
     .50   40.00    2.00   80.00  .263+16  .000    .000      .000
     .50   40.00    4.00   80.00  .105+17  .000    .000      .000
     .50   40.00    8.00   80.00  .420+17  .000    .000      .000
    4.00    1.00     .05     .25  .164+13  .415+00 .441+00   .441+10
    4.00    1.00     .10     .25  .657+13  .285+00 .369+00   .369+10
    4.00    1.00     .20     .25  .263+14  .634-01 .203+00   .203+10
    4.00    8.00     .40    2.00  .105+15  .679-03 .722-03   .722+07
    4.00    8.00     .80    2.00  .420+15  .467-03 .605-03   .605+07
    4.00    8.00    1.60    2.00  .168+16  .104-03 .332-03   .332+07
    4.00   40.00    2.00   10.00  .263+16  .165-10 .175-10   .175+00
    4.00   40.00    4.00   10.00  .105+17  .113-10 .147-10   .147+00
    4.00   40.00    8.00   10.00  .420+17  .253-11 .807-11   .807-01
   24.00    1.00     .05     .04  .164+13  .405+00 .431+00   .431+10
   24.00    1.00     .10     .04  .657+13  .278+00 .360+00   .360+10
   24.00    1.00     .20     .04  .263+14  .621-01 .198+00   .198+10
   24.00    8.00     .40     .33  .105+15  .624-02 .664-02   .664+08
   24.00    8.00     .80     .33  .420+15  .429-02 .556-02   .556+08
   24.00    8.00    1.60     .33  .168+16  .957-03 .305-02   .305+08
   24.00   40.00    2.00    1.67  .263+16  .464-04 .494-04   .494+06
   24.00   40.00    4.00    1.67  .105+17  .319-04 .414-04   .414+06
   24.00   40.00    8.00    1.67  .420+17  .712-05 .227-04   .227+06
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RADIONUCLIDE   CS 136
HALF LIFE   .137+02 DAYS
TOTAL RELEASE  .595+07 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .380-03 GRAMS PER CC
MAXIMUM PERMISSIBLE                                  .600-05     .140+00

 CURRENT    DOWN  RADIUS    TIME    VOLUME    CONCENTRATION AVE.SPEC.
VELOCITY CURRENT                               ISO-    AVE.  ACTIVITY
  NM/DAY      KM      KM    DAYS        CC   UCI/CC  UCI/CC    UCI/GM
     .50    1.00     .05    2.00  .164+13  .361-05 .389-05   .101-01
     .50    1.00     .10    2.00  .657+13  .248-05 .322-05   .846-02
     .50    1.00     .20    2.00  .263+14  .554-06 .177-05   .465-02
     .50    8.00     .40   16.00  .105+15  .278-07 .296-07   .779-04
     .50    8.00     .80   16.00  .420+15  .191-07 .248-07   .651-04
     .50    8.00    1.60   16.00  .168+16  .426-08 .136-07   .358-04
     .50   40.00    2.00   80.00  .263+16  .437-10 .464-10   .122-06
     .50   40.00    4.00   80.00  .105+17  .300-10 .389-10   .102-06
     .50   40.00    8.00   80.00  .420+17  .649-11 .214-10   .562-07
    4.00    1.00     .05     .25  .164+13  .395-05 .420-05   .110-01
    4.00    1.00     .10     .25  .657+13  .271-05 .351-05   .925-02
    4.00    1.00     .20     .25  .263+14  .605-06 .193-05   .508-02
    4.00    8.00     .40    2.00  .105+15  .564-07 .600-07   .158-03
    4.00    8.00     .80    2.00  .420+15  .388-07 .503-07   .132-03
    4.00    8.00    1.60    2.00  .168+16  .865-08 .276-07   .727-04
    4.00   40.00    2.00   10.00  .263+16  .151-08 .160-08   .422-05
    4.00   40.00    4.00   10.00  .105+17  .104-08 .134-08   .353-05
    4.00   40.00    8.00   10.00  .420+17  .231-09 .737-09   .194-05
   24.00    1.00     .05     .04  .164+13  .399-05 .424-05   .112-01
   24.00    1.00     .10     .04  .657+13  .274-05 .355-05   .934-02
   24.00    1.00     .20     .04  .263+14  .617-06 .195-05   .513-02
   24.00    8.00     .40     .33  .105+15  .614-07 .653-07   .172-03
   24.00    8.00     .80     .33  .420+15  .422-07 .547-07   .144-03
   24.00    8.00    1.60     .33  .168+16  .941-08 .300-07   .790-04
   24.00   40.00    2.00    1.67  .263+16  .239-08 .249-08   .693-05
   24.00   40.00    4.00    1.67  .105+17  .158-08 .204-08   .538-05
   24.00   40.00    8.00    1.67  .420+17  .352-09 .112-08   .296-05
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Down-current Distribution, BREACH-OF-CONTAINMENT Accident, Batch Release

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RADIONUCLIDE   CS 137
HALF LIFE    .109+05 DAYS
TOTAL RELEASE  .752+04 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .380-03 GRAMS PER CC
MAXIMUM PERMISSIBLE
                                                   .200-05      .210-01

 CURRENT     DOWN   RADIUS     TIME    VOLUME    CONCENTRATION AVE.SPEC.
VELOCITY CURRENT                                   ISO-    AVE.  ACTIVITY
  NM/DAY      NM       NM      DAYS         CC   UCI/CC  UCI/CC    UCI/GM
     .50    1.00      .05      2.00   .164+13  .505-03 .537-03   .141+01
     .50    1.00      .10      2.00   .657+13  .347-03 .450-03   .118+01
     .50    1.00      .20      2.00   .263+14  .774-04 .247-03   .650+00
     .50    8.00      .40     16.00   .105+15  .796-05 .839-05   .221-01
     .50    8.00      .80     16.00   .420+15  .542-05 .702-05   .195-01
     .50    8.00     1.60     16.00   .168+16  .121-05 .386-05   .101-01
     .50   40.00     2.00     80.00   .263+16  .314-06 .334-06   .879-03
     .50   40.00     4.00     80.00   .105+17  .216-06 .280-06   .736-03
     .50   40.00     8.00     80.00   .420+17  .482-07 .154-06   .404-03
    4.00    1.00      .05       .25   .164+13  .505-03 .537-03   .141+01
    4.00    1.00      .10       .25   .657+13  .347-03 .450-03   .118+01
    4.00    1.00      .20       .25   .263+14  .774-04 .247-03   .650+00
    4.00    8.00      .40      2.00   .105+15  .789-05 .839-05   .221-01
    4.00    8.00      .80      2.00   .420+15  .542-05 .703-05   .185-01
    4.00    8.00     1.60      2.00   .168+16  .121-05 .386-05   .102-01
    4.00   40.00     2.00     10.00   .263+16  .315-06 .336-06   .883-03
    4.00   40.00     4.00     10.00   .105+17  .217-06 .281-06   .739-03
    4.00   40.00     8.00     10.00   .420+17  .484-07 .154-06   .406-03
   24.00    1.00      .05       .04   .164+13  .505-03 .537-03   .141+01
   24.00    1.00      .10       .04   .657+13  .347-03 .450-03   .118+01
   24.00    1.00      .20       .04   .263+14  .774-04 .247-03   .650+00
   24.00    8.00      .40       .33   .105+15  .789-05 .839-05   .221-01
   24.00    8.00      .80       .33   .420+15  .542-05 .703-05   .185-01
   24.00    8.00     1.60       .33   .168+16  .121-05 .386-05   .102-01
   24.00   40.00     2.00      1.67   .263+16  .316-06 .336-06   .884-03
   24.00   40.00     4.00      1.67   .105+17  .217-06 .281-06   .740-03
   24.00   40.00     8.00      1.67   .420+17  .484-07 .154-06   .406-03
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RADIONUCLIDE   XE 138
HALF LIFE    .122-01 DAYS
TOTAL RELEASE  .933+06 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .100-09 GRAMS PER CC
MAXIMUM PERMISSIBLE
                                                   .000         .000

 CURRENT     DOWN   RADIUS     TIME    VOLUME    CONCENTRATION AVE.SPEC.
VELOCITY CURRENT                                   ISO-    AVE.  ACTIVITY
  NM/DAY      NM       NM      DAYS         CC   UCI/CC  UCI/CC    UCI/GM
     .50    1.00      .05      2.00   .164+13  .000    .000      .000
     .50    1.00      .10      2.00   .657+13  .000    .000      .000
     .50    1.00      .20      2.00   .263+14  .000    .000      .000
     .50    8.00      .40     16.00   .105+15  .000    .000      .000
     .50    8.00      .80     16.00   .420+15  .000    .000      .000
     .50    8.00     1.60     16.00   .168+16  .000    .000      .000
     .50   40.00     2.00     80.00   .263+16  .000    .000      .000
     .50   40.00     4.00     80.00   .105+17  .000    .000      .000
     .50   40.00     8.00     80.00   .420+17  .000    .000      .000
    4.00    1.00      .05       .25   .164+13  .413-07 .439-07   .439+03
    4.00    1.00      .10       .25   .657+13  .284-07 .367-07   .367+03
    4.00    1.00      .20       .25   .263+14  .633-09 .202-07   .202+03
    4.00    8.00      .40      2.00   .105+15  .000    .000      .000
    4.00    8.00      .80      2.00   .420+15  .000    .000      .000
    4.00    8.00     1.60      2.00   .168+16  .000    .000      .000
    4.00   40.00     2.00     10.00   .263+16  .000    .000      .000
    4.00   40.00     4.00     10.00   .105+17  .000    .000      .000
    4.00   40.00     8.00     10.00   .420+17  .000    .000      .000
   24.00    1.00      .05       .04   .164+13  .569-02 .605-02   .605+08
   24.00    1.00      .10       .04   .657+13  .391-02 .506-02   .506+08
   24.00    1.00      .20       .04   .263+14  .872-03 .278-02   .278+08
   24.00    8.00      .40       .33   .105+15  .567-11 .603-11   .603-01
   24.00    8.00      .80       .33   .420+15  .390-11 .505-11   .505-01
   24.00    8.00     1.60       .33   .168+16  .869-12 .277-11   .277-01
   24.00   40.00     2.00      1.67   .263+16  .000    .000      .000
   24.00   40.00     4.00      1.67   .105+17  .000    .000      .000
   24.00   40.00     8.00      1.67   .420+17  .000    .000      .000
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Down-current Distribution, BREACH-OF-CONTAINMENT Accident, Batch Release

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RADIONUCLIDE   CS 138
HALF LIFE   .224-01 DAYS
TOTAL RELEASE   .267+03 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER   .380-03 GRAMS PER CC
MAXIMUM PERMISSIBLE                                    .000        .000
DAUGHTER OF PREVIOUS RADIONUCLIDE, DECAY FRACTION =  1.0000

 CURRENT     DOWN   RADIUS     TIME    VOLUME    CONCENTRATION AVE.SPEC.
VELOCITY  CURRENT                                 ISO-     AVE.  ACTIVITY
  KM/DAY       KM       KM     DAYS        CC   UCI/CC   UCI/CC    UCI/GM
     .50     1.00      .05     2.00  .164+13  .974-28  .104-27  .273-24
     .50     1.00      .10     2.00  .657+13  .670-28  .868-28  .228-24
     .50     1.00      .20     2.00  .263+14  .149-28  .477-28  .125-24
     .50     8.00      .40    16.00  .105+15  .000     .000     .000
     .50     8.00      .80    16.00  .420+15  .000     .000     .000
     .50     8.00     1.60    16.00  .168+16  .000     .000     .000
     .50    40.00     2.00    80.00  .263+16  .000     .000     .000
     .50    40.00     4.00    80.00  .105+17  .000     .000     .000
     .50    40.00     8.00    80.00  .420+17  .000     .000     .000
    4.00     1.00      .05      .25  .164+13  .317-04  .337-04  .887-01
    4.00     1.00      .10      .25  .657+13  .219-04  .282-04  .743-01
    4.00     1.00      .20      .25  .263+14  .994-05  .155-04  .408-01
    4.00     8.00      .40     2.00  .105+15  .152-29  .162-29  .426-26
    4.00     8.00      .80     2.00  .420+15  .105-29  .136-29  .357-26
    4.00     8.00     1.60     2.00  .168+16  .233-30  .745-30  .196-26
    4.00    40.00     2.00    10.00  .263+16  .000     .000     .000
    4.00    40.00     4.00    10.00  .105+17  .000     .000     .000
    4.00    40.00     8.00    10.00  .420+17  .000     .000     .000
   24.00     1.00      .05      .04  .164+13  .132-01  .140-01  .369+02
   24.00     1.00      .10      .04  .657+13  .976-02  .117-01  .309+02
   24.00     1.00      .20      .04  .263+14  .202-02  .645-02  .170+02
   24.00     8.00      .40      .33  .105+15  .374-07  .400-07  .105-03
   24.00     8.00      .80      .33  .420+15  .259-07  .335-07  .882-04
   24.00     8.00     1.60      .33  .168+16  .577-08  .184-07  .485-04
   24.00    40.00     2.00     1.67  .263+16  .193-26  .195-26  .513-23
   24.00    40.00     4.00     1.67  .105+17  .176-26  .163-26  .430-23
   24.00    40.00     8.00     1.67  .420+17  .281-27  .897-27  .236-23
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RADIONUCLIDE   BA 140
HALF LIFE   .128+02 DAYS
TOTAL RELEASE   .339+01 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER   .300-07 GRAMS PER CC
MAXIMUM PERMISSIBLE
                                                  .320-05      .150+03

 CURRENT     DOWN   RADIUS     TIME    VOLUME    CONCENTRATION AVE.SPEC.
VELOCITY  CURRENT                                 ISO-     AVE.  ACTIVITY
  KM/DAY       KM       KM     DAYS        CC   UCI/CC   UCI/CC    UCI/GM
     .50     1.00      .05     2.00  .164+13  .183-06  .195-06  .650+01
     .50     1.00      .10     2.00  .657+13  .126-06  .163-06  .544+01
     .50     1.00      .20     2.00  .263+14  .291-07  .896-07  .299+01
     .50     8.00      .40    16.00  .105+15  .134-08  .143-08  .476-01
     .50     8.00      .80    16.00  .420+15  .922-09  .119-08  .398-01
     .50     8.00     1.60    16.00  .168+16  .206-09  .656-09  .219-01
     .50    40.00     2.00    80.00  .263+16  .168-11  .179-11  .595-04
     .50    40.00     4.00    80.00  .105+17  .115-11  .149-11  .498-04
     .50    40.00     8.00    80.00  .420+17  .257-12  .821-12  .274-04
    4.00     1.00      .05      .25  .164+13  .201-06  .214-06  .714+01
    4.00     1.00      .10      .25  .657+13  .138-06  .179-06  .598+01
    4.00     1.00      .20      .25  .263+14  .309-07  .985-07  .328+01
    4.00     8.00      .40     2.00  .105+15  .296-08  .305-08  .102+00
    4.00     8.00      .80     2.00  .420+15  .197-08  .255-08  .850-01
    4.00     8.00     1.60     2.00  .168+16  .439-09  .140-08  .467-01
    4.00    40.00     2.00    10.00  .263+16  .743-10  .790-10  .263-02
    4.00    40.00     4.00    10.00  .105+17  .510-10  .661-10  .220-02
    4.00    40.00     8.00    10.00  .420+17  .114-10  .363-10  .121-02
   24.00     1.00      .05      .04  .164+13  .204-06  .217-06  .722+01
   24.00     1.00      .10      .04  .657+13  .140-06  .181-06  .605+01
   24.00     1.00      .20      .04  .263+14  .312-07  .997-07  .332+01
   24.00     8.00      .40      .33  .105+15  .313-08  .333-08  .111+00
   24.00     8.00      .80      .33  .420+15  .215-08  .279-08  .930-01
   24.00     8.00     1.60      .33  .168+16  .480-09  .153-08  .511-01
   24.00    40.00     2.00     1.67  .263+16  .117-09  .124-09  .413-02
   24.00    40.00     4.00     1.67  .105+17  .801-10  .104-09  .346-02
   24.00    40.00     8.00     1.67  .420+17  .179-10  .570-10  .190-02
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Down-current Distribution, BREACH-OF-CONTAINMENT Accident, Batch Release

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RADIONUCLIDE   LA 140
HALF LIFE   .168+01 DAYS
TOTAL RELEASE  .296+01 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .300-08 GRAMS PER CC
MAXIMUM PERMISSIBLE                                    .380-06      .480+04
DAUGHTER OF PREVIOUS RADIONUCLIDE, DECAY FRACTION =  1.0000

 CURRENT     DOWN   RADIUS     TIME    VOLUME    CONCENTRATION AVE.SPEC.
VELOCITY CURRENT                                   ISO-    AVE.  ACTIVITY
  NM/DAY      NM       NM      DAYS        CC   UCI/CC  UCI/CC    UCI/GM
     .50    1.00      .05      2.00  .164+13  .195-06 .207-06   .691+03
     .50    1.00      .10      2.00  .657+13  .134-06 .174-06   .579+03
     .50    1.00      .20      2.00  .263+14  .299-07 .954-07   .318+03
     .50    8.00      .40     16.00  .105+15  .154-08 .164-08   .547+01
     .50    8.00      .80     16.00  .420+15  .104-08 .137-08   .456+01
     .50    8.00     1.60     16.00  .168+16  .237-09 .755-09   .252+01
     .50   40.00     2.00     80.00  .263+16  .193-11 .205-11   .685-02
     .50   40.00     4.00     80.00  .105+17  .133-11 .172-11   .573-02
     .50   40.00     8.00     80.00  .420+17  .296-12 .945-12   .315-02
    4.00    1.00      .05       .25  .164+13  .199-06 .212-06   .706+03
    4.00    1.00      .10       .25  .657+13  .137-06 .177-06   .591+03
    4.00    1.00      .20       .25  .263+14  .306-07 .974-07   .325+03
    4.00    8.00      .40      2.00  .105+15  .305-08 .324-08   .108+02
    4.00    8.00      .80      2.00  .420+15  .208-08 .271-08   .904+01
    4.00    8.00     1.60      2.00  .168+16  .467-09 .149-08   .497+01
    4.00   40.00     2.00     10.00  .263+16  .851-10 .905-10   .302+00
    4.00   40.00     4.00     10.00  .105+17  .585-10 .758-10   .253+00
    4.00   40.00     8.00     10.00  .420+17  .130-10 .416-10   .139+00
   24.00    1.00      .05       .04  .164+13  .199-06 .212-06   .705+03
   24.00    1.00      .10       .04  .657+13  .137-06 .177-06   .590+03
   24.00    1.00      .20       .04  .263+14  .305-07 .973-07   .324+03
   24.00    8.00      .40       .33  .105+15  .311-08 .331-08   .110+02
   24.00    8.00      .80       .33  .420+15  .214-08 .277-08   .924+01
   24.00    8.00     1.60       .33  .168+16  .477-09 .152-08   .508+01
   24.00   40.00     2.00      1.67  .263+16  .123-09 .131-09   .436+00
   24.00   40.00     4.00      1.67  .105+17  .844-10 .109-09   .365+00
   24.00   40.00     8.00      1.67  .420+17  .188-10 .601-10   .200+00
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RADIONUCLIDE   CE 141
HALF LIFE   .325+02 DAYS
TOTAL RELEASE  .273+01 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .300-08 GRAMS PER CC
MAXIMUM PERMISSIBLE                                    .170-05      .120+04

 CURRENT     DOWN   RADIUS     TIME    VOLUME    CONCENTRATION AVE.SPEC.
VELOCITY CURRENT                                   ISO-    AVE.  ACTIVITY
  NM/DAY      NM       NM      DAYS        CC   UCI/CC  UCI/CC    UCI/GM
     .50    1.00      .05      2.00  .164+13  .176-06 .187-06   .623+03
     .50    1.00      .10      2.00  .657+13  .121-06 .156-06   .522+03
     .50    1.00      .20      2.00  .263+14  .269-07 .860-07   .287+03
     .50    8.00      .40     16.00  .105+15  .204-08 .217-08   .722+01
     .50    8.00      .80     16.00  .420+15  .140-08 .181-08   .605+01
     .50    8.00     1.60     16.00  .168+16  .312-09 .996-09   .332+01
     .50   40.00     2.00     80.00  .263+16  .208-10 .221-10   .738-01
     .50   40.00     4.00     80.00  .105+17  .143-10 .185-10   .618-01
     .50   40.00     8.00     80.00  .420+17  .319-11 .102-10   .339-01
    4.00    1.00      .05       .25  .164+13  .182-06 .194-06   .647+03
    4.00    1.00      .10       .25  .657+13  .125-06 .162-06   .541+03
    4.00    1.00      .20       .25  .263+14  .280-07 .892-07   .297+03
    4.00    8.00      .40      2.00  .105+15  .275-08 .292-08   .973+01
    4.00    8.00      .80      2.00  .420+15  .189-08 .244-08   .815+01
    4.00    8.00     1.60      2.00  .168+16  .421-09 .134-08   .448+01
    4.00   40.00     2.00     10.00  .263+16  .926-10 .985-10   .328+00
    4.00   40.00     4.00     10.00  .105+17  .636-10 .825-10   .275+00
    4.00   40.00     8.00     10.00  .420+17  .142-10 .453-10   .151+00
   24.00    1.00      .05       .04  .164+13  .183-06 .195-06   .650+03
   24.00    1.00      .10       .04  .657+13  .126-06 .163-06   .544+03
   24.00    1.00      .20       .04  .263+14  .281-07 .896-07   .299+03
   24.00    8.00      .40       .33  .105+15  .284-08 .303-08   .101+02
   24.00    8.00      .80       .33  .420+15  .195-08 .253-08   .844+01
   24.00    8.00     1.60       .33  .168+16  .436-09 .139-08   .464+01
   24.00   40.00     2.00      1.67  .263+16  .111-09 .118-09   .392+00
   24.00   40.00     4.00      1.67  .105+17  .760-10 .985-10   .328+00
   24.00   40.00     8.00      1.67  .420+17  .170-10 .541-10   .180+00
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Down-current Distribution, BREACH-OF-CONTAINMENT Accident, Batch Release

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RADIONUCLIDE   CE 143
HALF LIFE   .137+01 DAYS
TOTAL RELEASE  .261+01 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .300-09 GRAMS PER CC
MAXIMUM PERMISSIBLE                                    .760-06     .680+04

 CURRENT     DOWN   RADIUS     TIME    VOLUME    CONCENTRATION AVE.SPEC.
VELOCITY CURRENT                                   ISO-    AVE.  ACTIVITY
  KM/DAY      KM      KM      DAYS         CC   UCI/CC  UCI/CC    UCI/GM
     .50    1.00     .05      2.00  .164+13  .660-07 .680-07   .227+03
     .50    1.00     .10      2.00  .657+13  .940-07 .570-07   .190+03
     .50    1.00     .20      2.00  .263+14  .981-08 .313-07   .104+03
     .50    8.00     .40     16.00  .105+15  .462-12 .917-12   .306-02
     .50    8.00     .80     16.00  .420+15  .592-12 .767-12   .256-02
     .50    8.00    1.60     16.00  .168+16  .132-12 .422-12   .141-02
     .50   40.00    2.00     80.00  .263+16  .338-27 .360-27   .120-17
     .50   40.00    4.00     80.00  .105+17  .232-27 .301-27   .100-17
     .50   40.00    8.00     80.00  .420+17  .518-28 .165-27   .551-18
    4.00    1.00     .05       .25  .164+13  .155-06 .164-06   .548+03
    4.00    1.00     .10       .25  .657+13  .104-06 .138-06   .459+03
    4.00    1.00     .20       .25  .263+14  .237-07 .756-07   .252+03
    4.00    8.00     .40      2.00  .105+15  .100-08 .106-08   .354+01
    4.00    8.00     .80      2.00  .420+15  .687-09 .890-09   .297+01
    4.00    8.00    1.60      2.00  .168+16  .153-09 .489-09   .163+01
    4.00   40.00    2.00     10.00  .263+16  .709-12 .754-12   .251-02
    4.00   40.00    4.00     10.00  .105+17  .447-12 .632-12   .211-02
    4.00   40.00    8.00     10.00  .420+17  .109-12 .347-12   .116-02
   24.00    1.00     .05       .04  .164+13  .172-06 .183-06   .609+03
   24.00    1.00     .10       .04  .657+13  .119-06 .153-06   .510+03
   24.00    1.00     .20       .04  .263+14  .243-07 .840-07   .280+03
   24.00    8.00     .40       .33  .105+15  .232-08 .246-08   .821+01
   24.00    8.00     .80       .33  .420+15  .159-08 .206-08   .687+01
   24.00    8.00    1.60       .33  .168+16  .355-09 .113-08   .378+01
   24.00   40.00    2.00      1.67  .263+16  .473-10 .503-10   .168+00
   24.00   40.00    4.00      1.67  .105+17  .326-10 .421-10   .140+00
   24.00   40.00    8.00      1.67  .420+17  .725-11 .231-10   .771-01
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RADIONUCLIDE   PR 143
HALF LIFE   .136+02 DAYS
TOTAL RELEASE  .269+01 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .300-09 GRAMS PER CC
MAXIMUM PERMISSIBLE                                  .950-07     .180+04
DAUGHTER OF PREVIOUS RADIONUCLIDE, DECAY FRACTION =  1.0000

 CURRENT     DOWN   RADIUS     TIME    VOLUME    CONCENTRATION AVE.SPEC.
VELOCITY CURRENT                                   ISO-    AVE.  ACTIVITY
  KM/DAY      KM      KM      DAYS         CC   UCI/CC  UCI/CC    UCI/GM
     .50    1.00     .05      2.00  .164+13  .174-06 .184-06   .614+03
     .50    1.00     .10      2.00  .657+13  .119-06 .155-06   .516+03
     .50    1.00     .20      2.00  .263+14  .266-07 .850-07   .283+03
     .50    8.00     .40     16.00  .105+15  .139-08 .147-08   .491+01
     .50    8.00     .80     16.00  .420+15  .952-09 .123-08   .411+01
     .50    8.00    1.60     16.00  .168+16  .217-09 .677-09   .226+01
     .50   40.00    2.00     80.00  .263+16  .212-11 .225-11   .751-02
     .50   40.00    4.00     80.00  .105+17  .146-11 .189-11   .629-02
     .50   40.00    8.00     80.00  .420+17  .325-12 .104-11   .346-02
    4.00    1.00     .05       .25  .164+13  .180-06 .192-06   .640+03
    4.00    1.00     .10       .25  .657+13  .129-06 .161-06   .536+03
    4.00    1.00     .20       .25  .263+14  .277-07 .883-07   .294+03
    4.00    8.00     .40      2.00  .105+15  .271-08 .289-08   .963+01
    4.00    8.00     .80      2.00  .420+15  .187-08 .242-08   .806+01
    4.00    8.00    1.60      2.00  .168+16  .416-09 .133-08   .443+01
    4.00   40.00    2.00     10.00  .263+16  .751-10 .799-10   .266+00
    4.00   40.00    4.00     10.00  .105+17  .516-10 .669-10   .223+00
    4.00   40.00    8.00     10.00  .420+17  .115-10 .368-10   .123+00
   24.00    1.00     .05       .04  .164+13  .181-06 .192-06   .641+03
   24.00    1.00     .10       .04  .657+13  .129-06 .161-06   .536+03
   24.00    1.00     .20       .04  .263+14  .277-07 .884-07   .295+03
   24.00    8.00     .40       .33  .105+15  .282-08 .300-08   .999+01
   24.00    8.00     .80       .33  .420+15  .194-08 .251-08   .836+01
   24.00    8.00    1.60       .33  .168+16  .432-09 .138-08   .460+01
   24.00   40.00    2.00      1.67  .263+16  .110-09 .117-09   .389+00
   24.00   40.00    4.00      1.67  .105+17  .754-10 .977-10   .326+00
   24.00   40.00    8.00      1.67  .420+17  .168-10 .537-10   .179+00
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Down-current Distribution, BREACH-OF-CONTAINMENT Accident, Batch Release

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RADIONUCLIDE   CE 144
HALF LIFE    .284+03 DAYS
TOTAL RELEASE   .186+01 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER   .300-09 GRAMS PER CC
MAXIMUM PERMISSIBLE                                .190-06     .230+02

 CURRENT     DOWN   RADIUS      TIME     VOLUME    CONCENTRATION AVE.SPEC.
VELOCITY  CURRENT                                    ISO-     AVE.  ACTIVITY
  NM/DAY       NM       NM      DAYS         CC    UCI/CC   UCI/CC    UCI/GM
     .50     1.00      .05      2.00   .164+13  .124-06  .132-06   .441+03
     .50     1.00      .10      2.00   .657+13  .854-07  .111-06   .369+03
     .50     1.00      .20      2.00   .263+14  .191-07  .608-07   .203+03
     .50     8.00      .40     16.00   .105+15  .188-08  .200-08   .666+01
     .50     8.00      .80     16.00   .420+15  .129-08  .167-08   .557+01
     .50     8.00     1.60     16.00   .168+16  .289-09  .918-09   .306+01
     .50    40.00     2.00     80.00   .263+16  .642-10  .683-10   .228+00
     .50    40.00     4.00     80.00   .105+17  .441-10  .572-10   .191+00
     .50    40.00     8.00     80.00   .420+17  .985-11  .314-10   .105+00
    4.00     1.00      .05       .25   .164+13  .125-06  .133-06   .443+03
    4.00     1.00      .10       .25   .657+13  .858-07  .111-06   .371+03
    4.00     1.00      .20       .25   .263+14  .191-07  .611-07   .204+03
    4.00     8.00      .40      2.00   .105+15  .194-08  .207-08   .689+01
    4.00     8.00      .80      2.00   .420+15  .133-08  .173-08   .577+01
    4.00     8.00     1.60      2.00   .168+16  .298-09  .950-09   .317+01
    4.00    40.00     2.00     10.00   .263+16  .762-10  .810-10   .270+00
    4.00    40.00     4.00     10.00   .105+17  .524-10  .679-10   .226+00
    4.00    40.00     8.00     10.00   .420+17  .117-10  .373-10   .124+00
   24.00     1.00      .05       .04   .164+13  .125-06  .133-06   .443+03
   24.00     1.00      .10       .04   .657+13  .858-07  .111-06   .371+03
   24.00     1.00      .20       .04   .263+14  .192-07  .611-07   .204+03
   24.00     8.00      .40       .33   .105+15  .195-08  .207-08   .692+01
   24.00     8.00      .80       .33   .420+15  .134-08  .174-08   .579+01
   24.00     8.00     1.60       .33   .168+16  .299-09  .954-09   .318+01
   24.00    40.00     2.00      1.67   .263+16  .779-10  .827-10   .276+00
   24.00    40.00     4.00      1.67   .105+17  .534-10  .692-10   .231+00
   24.00    40.00     8.00      1.67   .420+17  .119-10  .380-10   .127+00
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RADIONUCLIDE   PR 145
HALF LIFE    .249+00 DAYS
TOTAL RELEASE   .397+00 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER   .300-09 GRAMS PER CC
MAXIMUM PERMISSIBLE                                .000        .000

 CURRENT     DOWN   RADIUS      TIME     VOLUME    CONCENTRATION AVE.SPEC.
VELOCITY  CURRENT                                    ISO-     AVE.  ACTIVITY
  NM/DAY       NM       NM      DAYS         CC    UCI/CC   UCI/CC    UCI/GM
     .50     1.00      .05      2.00   .164+13  .102-09  .108-09   .362+00
     .50     1.00      .10      2.00   .657+13  .701-10  .908-10   .303+00
     .50     1.00      .20      2.00   .263+14  .156-10  .499-10   .166+00
     .50     8.00      .40     16.00   .105+15  .191-28  .203-28   .676-19
     .50     8.00      .80     16.00   .420+15  .131-28  .170-28   .566-19
     .50     8.00     1.60     16.00   .168+16  .293-29  .933-29   .311-19
     .50    40.00     2.00     80.00   .263+16  .000     .000      .000
     .50    40.00     4.00     80.00   .105+17  .000     .000      .000
     .50    40.00     8.00     80.00   .420+17  .000     .000      .000
    4.00     1.00      .05       .25   .164+13  .133-07  .141-07   .471+02
    4.00     1.00      .10       .25   .657+13  .914-08  .118-07   .395+02
    4.00     1.00      .20       .25   .263+14  .204-08  .650-08   .217+02
    4.00     8.00      .40      2.00   .105+15  .159-11  .169-11   .565-02
    4.00     8.00      .80      2.00   .420+15  .110-11  .142-11   .473-02
    4.00     8.00     1.60      2.00   .168+16  .244-12  .780-12   .260-02
    4.00    40.00     2.00     10.00   .263+16  .136-22  .145-22   .484-13
    4.00    40.00     4.00     10.00   .105+17  .937-23  .121-22   .405-13
    4.00    40.00     8.00     10.00   .420+17  .209-23  .667-23   .222-13
   24.00     1.00      .05       .04   .164+13  .237-07  .253-07   .842+02
   24.00     1.00      .10       .04   .657+13  .143-07  .211-07   .705+02
   24.00     1.00      .20       .04   .263+14  .364-08  .116-07   .387+02
   24.00     8.00      .40       .33   .105+15  .165-09  .175-09   .584+00
   24.00     8.00      .80       .33   .420+15  .113-09  .147-09   .489+00
   24.00     8.00     1.60       .33   .168+16  .253-10  .806-10   .269+00
   24.00    40.00     2.00      1.67   .263+16  .161-12  .171-12   .571-03
   24.00    40.00     4.00      1.67   .105+17  .111-12  .144-12   .478-03
   24.00    40.00     8.00      1.67   .420+17  .247-13  .789-13   .263-03
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Down-current Distribution, BREACH-OF-CONTAINMENT Accident, Batch Release

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RADIONUCLIDE    ND 147
HALF LIFE    .111+02 DAYS
TOTAL RELEASE   .931+00 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER   .300-09 GRAMS PER CC
MAXIMUM PERMISSIBLE                                    .110-06      .190+04

 CURRENT      DOWN   RADIUS      TIME     VOLUME     CONCENTRATION AVE.SPEC.
VELOCITY  CURRENT                                      ISO-    AVE.  ACTIVITY
  NM/DAY       NM       NM      DAYS          CC    UCI/CC  UCI/CC    UCI/GM
     .50     1.00      .05      2.00    .164+13   .552-07 .587-07   .196+03
     .50     1.00      .10      2.00    .657+13   .379-07 .491-07   .164+03
     .50     1.00      .20      2.00    .263+14   .896-08 .270-07   .900+02
     .50     8.00      .40     16.00    .105+15   .358-09 .381-09   .127+01
     .50     8.00      .80     16.00    .420+15   .246-09 .319-09   .106+01
     .50     8.00     1.60     16.00    .168+16   .550-10 .175-09   .585+00
     .50    40.00     2.00     80.00    .263+16   .260-12 .277-12   .922-03
     .50    40.00     4.00     80.00    .105+17   .179-12 .232-12   .772-03
     .50    40.00     8.00     80.00    .420+17   .399-13 .127-12   .424-03
    4.00     1.00      .05       .25    .164+13   .616-07 .655-07   .218+03
    4.00     1.00      .10       .25    .657+13   .423-07 .549-07   .183+03
    4.00     1.00      .20       .25    .263+14   .944-08 .301-07   .100+03
    4.00     8.00      .40      2.00    .105+15   .862-09 .917-09   .306+01
    4.00     8.00      .80      2.00    .420+15   .592-09 .760-09   .254+01
    4.00     8.00     1.60      2.00    .168+16   .132-09 .422-09   .141+01
    4.00    40.00     2.00     10.00    .263+16   .209-10 .222-10   .741-01
    4.00    40.00     4.00     10.00    .105+17   .144-10 .186-10   .620-01
    4.00    40.00     8.00     10.00    .420+17   .320-11 .102-10   .341-01
   24.00     1.00      .05       .04    .164+13   .624-07 .663-07   .221+03
   24.00     1.00      .10       .04    .657+13   .429-07 .555-07   .185+03
   24.00     1.00      .20       .04    .263+14   .956-08 .305-07   .102+03
   24.00     8.00      .40       .33    .105+15   .957-09 .102-08   .339+01
   24.00     8.00      .80       .33    .420+15   .658-09 .852-09   .284+01
   24.00     8.00     1.60       .33    .168+16   .147-09 .468-09   .156+01
   24.00    40.00     2.00      1.67    .263+16   .352-10 .374-10   .125+00
   24.00    40.00     4.00      1.67    .105+17   .242-10 .313-10   .104+00
   24.00    40.00     8.00      1.67    .420+17   .540-11 .172-10   .574-01
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RADIONUCLIDE    PM 147
HALF LIFE    .629+02 DAYS
TOTAL RELEASE   .369+00 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER   .300-09 GRAMS PER CC
MAXIMUM PERMISSIBLE                                    .380-06      .160+03
DAUGHTER OF PREVIOUS RADIONUCLIDE, DECAY FRACTION =  1.0000

 CURRENT      DOWN   RADIUS      TIME     VOLUME     CONCENTRATION AVE.SPEC.
VELOCITY  CURRENT                                      ISO-    AVE.  ACTIVITY
  NM/DAY       NM       NM      DAYS          CC    UCI/CC  UCI/CC    UCI/GM
     .50     1.00      .05      2.00    .164+13   .255-07 .271-07   .903+02
     .50     1.00      .10      2.00    .657+13   .175-07 .227-07   .756+02
     .50     1.00      .20      2.00    .263+14   .390-08 .125-07   .415+02
     .50     8.00      .40     16.00    .105+15   .422-09 .449-09   .150+01
     .50     8.00      .80     16.00    .420+15   .290-09 .376-09   .125+01
     .50     8.00     1.60     16.00    .168+16   .647-10 .206-09   .689+00
     .50    40.00     2.00     80.00    .263+16   .990-11 .104-10   .347-01
     .50    40.00     4.00     80.00    .105+17   .673-11 .872-11   .291-01
     .50    40.00     8.00     80.00    .420+17   .150-11 .479-11   .160-01
    4.00     1.00      .05       .25    .164+13   .248-07 .264-07   .880+02
    4.00     1.00      .10       .25    .657+13   .171-07 .221-07   .737+02
    4.00     1.00      .20       .25    .263+14   .381-08 .121-07   .405+02
    4.00     8.00      .40      2.00    .105+15   .398-09 .423-09   .141+01
    4.00     8.00      .80      2.00    .420+15   .273-09 .354-09   .118+01
    4.00     8.00     1.60      2.00    .168+16   .610-10 .195-09   .649+00
    4.00    40.00     2.00     10.00    .263+16   .168-10 .179-10   .597-01
    4.00    40.00     4.00     10.00    .105+17   .116-10 .150-10   .500-01
    4.00    40.00     8.00     10.00    .420+17   .258-11 .824-11   .275-01
   24.00     1.00      .05       .04    .164+13   .247-07 .263-07   .877+02
   24.00     1.00      .10       .04    .657+13   .170-07 .220-07   .734+02
   24.00     1.00      .20       .04    .263+14   .379-08 .121-07   .403+02
   24.00     8.00      .40       .33    .105+15   .388-09 .413-09   .138+01
   24.00     8.00      .80       .33    .420+15   .267-09 .346-09   .115+01
   24.00     8.00     1.60       .33    .168+16   .595-10 .190-09   .633+00
   24.00    40.00     2.00      1.67    .263+16   .158-10 .169-10   .562-01
   24.00    40.00     4.00      1.67    .105+17   .109-10 .141-10   .470-01
   24.00    40.00     8.00      1.67    .420+17   .243-11 .775-11   .258-01
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Down-current Distribution, BREACH-OF-CONTAINMENT Accident, Batch Release

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RADIONUCLIDE   PM 149
HALF LIFE   .221+01 DAYS
TOTAL RELEASE  .353+00 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .300-09 GRAMS PER CC
MAXIMUM PERMISSIBLE                                  .760-07     .950+04

 CURRENT    DOWN  RADIUS    TIME    VOLUME   CONCENTRATION AVE.SPEC.
VELOCITY CURRENT                              ISO-    AVE.  ACTIVITY
  NM/DAY      NM      NM    DAYS        CC  UCI/CC  UCI/CC    UCI/GM
     .50    1.00     .05    2.00   .164+13 .127-07 .135-07   .449+02
     .50    1.00     .10    2.00   .657+13 .870-08 .113-07   .376+02
     .50    1.00     .20    2.00   .263+14 .194-08 .619-08   .206+02
     .50    8.00     .40   16.00   .105+15 .245-11 .261-11   .870-02
     .50    8.00     .80   16.00   .420+15 .169-11 .218-11   .728-02
     .50    8.00    1.60   16.00   .168+16 .376-12 .120-11   .400-02
     .50   40.00    2.00   80.00   .263+16 .189-21 .201-21   .670-12
     .50   40.00    4.00   80.00   .105+17 .130-21 .168-21   .561-12
     .50   40.00    8.00   80.00   .420+17 .290-22 .924-22   .308-12
    4.00    1.00     .05     .25   .164+13 .219-07 .233-07   .777+02
    4.00    1.00     .10     .25   .657+13 .151-07 .195-07   .651+02
    4.00    1.00     .20     .25   .263+14 .336-08 .107-07   .357+02
    4.00    8.00     .40    2.00   .105+15 .198-09 .210-09   .702+00
    4.00    8.00     .80    2.00   .420+15 .136-09 .176-09   .587+00
    4.00    8.00    1.60    2.00   .168+16 .303-10 .968-10   .323+00
    4.00   40.00    2.00   10.00   .263+16 .644-12 .685-12   .228-02
    4.00   40.00    4.00   10.00   .105+17 .443-12 .574-12   .191-02
    4.00   40.00    8.00   10.00   .420+17 .988-13 .315-12   .105-02
   24.00    1.00     .05     .04   .164+13 .234-07 .249-07   .830+02
   24.00    1.00     .10     .04   .657+13 .161-07 .208-07   .695+02
   24.00    1.00     .20     .04   .263+14 .359-08 .114-07   .382+02
   24.00    8.00     .40     .33   .105+15 .334-09 .355-09   .118+01
   24.00    8.00     .80     .33   .420+15 .229-09 .297-09   .990+00
   24.00    8.00    1.60     .33   .168+16 .512-10 .163-09   .544+00
   24.00   40.00    2.00    1.67   .263+16 .879-11 .935-11   .312-01
   24.00   40.00    4.00    1.67   .105+17 .604-11 .782-11   .261-01
   24.00   40.00    8.00    1.67   .420+17 .135-11 .430-11   .143-01
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RADIONUCLIDE   PM 151
HALF LIFE   .116+01 DAYS
TOTAL RELEASE  .110+00 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .300-09 GRAMS PER CC
MAXIMUM PERMISSIBLE                               .000        .000

 CURRENT    DOWN  RADIUS    TIME    VOLUME   CONCENTRATION AVE.SPEC.
VELOCITY CURRENT                              ISO-    AVE.  ACTIVITY
  NM/DAY      NM      NM    DAYS        CC  UCI/CC  UCI/CC    UCI/GM
     .50    1.00     .05    2.00   .164+13 .224-08 .238-08   .793+01
     .50    1.00     .10    2.00   .657+13 .154-08 .199-08   .664+01
     .50    1.00     .20    2.00   .263+14 .343-09 .104-08   .345+01
     .50    8.00     .40   16.00   .105+15 .815-14 .867-14   .289-04
     .50    8.00     .80   16.00   .420+15 .560-14 .726-14   .242-04
     .50    8.00    1.60   16.00   .168+16 .125-14 .399-14   .133-04
     .50   40.00    2.00   80.00   .263+16 .809-32 .861-32   .287-22
     .50   40.00    4.00   80.00   .105+17 .556-32 .721-32   .240-22
     .50   40.00    8.00   80.00   .420+17 .124-32 .396-32   .132-22
    4.00    1.00     .05     .25   .164+13 .634-08 .677-08   .226+02
    4.00    1.00     .10     .25   .657+13 .437-08 .567-08   .189+02
    4.00    1.00     .20     .25   .263+14 .976-09 .311-08   .104+02
    4.00    8.00     .40    2.00   .105+15 .349-10 .372-10   .124+00
    4.00    8.00     .80    2.00   .420+15 .240-10 .311-10   .104+00
    4.00    8.00    1.60    2.00   .168+16 .536-11 .171-10   .570-01
    4.00   40.00    2.00   10.00   .263+16 .117-13 .125-13   .416-04
    4.00   40.00    4.00   10.00   .105+17 .807-14 .105-13   .349-04
    4.00   40.00    8.00   10.00   .420+17 .180-14 .575-14   .192-04
   24.00    1.00     .05     .04   .164+13 .721-08 .767-08   .256+02
   24.00    1.00     .10     .04   .657+13 .495-08 .642-08   .214+02
   24.00    1.00     .20     .04   .263+14 .111-08 .353-08   .118+02
   24.00    8.00     .40     .33   .105+15 .946-10 .101-09   .335+00
   24.00    8.00     .80     .33   .420+15 .650-10 .842-10   .281+00
   24.00    8.00    1.60     .33   .168+16 .145-10 .463-10   .154+00
   24.00   40.00    2.00    1.67   .263+16 .171-11 .181-11   .605-02
   24.00   40.00    4.00    1.67   .105+17 .117-11 .152-11   .506-02
   24.00   40.00    8.00    1.67   .420+17 .262-12 .835-12   .278-02
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Down-current Distribution, BREACH-OF-CONTAINMENT Accident, Batch Release

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RADIONUCLIDE   SM 151
HALF LIFE   .318+05 DAYS
TOTAL RELEASE  .271-02 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .300-09 GRAMS PER CC
MAXIMUM PERMISSIBLE                                   .500-06     .160+03
DAUGHTER OF PREVIOUS RADIONUCLIDE. DECAY FRACTION =  1.0000

 CURRENT     DOWN  RADIUS     TIME    VOLUME    CONCENTRATION AVE.SPEC.
VELOCITY CURRENT
  NM/DAY      NM      NM                              150-    AVE.  ACTIVITY
                               DAYS        CC    UCI/CC  UCI/CC    UCI/GM
     .50    1.00     .05     2.00  .164+13  .182-09 .194-09   .646+00
     .50    1.00     .10     2.00  .657+13  .125-09 .162-09   .541+00
     .50    1.00     .20     2.00  .263+14  .279-10 .891-10   .297+00
     .50    8.00     .40    16.00  .105+15  .285-11 .303-11   .101-01
     .50    8.00     .80    16.00  .420+15  .196-11 .254-11   .845-02
     .50    8.00    1.60    16.00  .168+16  .437-12 .139-11   .464-02
     .50   40.00    2.00    80.00  .263+16  .114-12 .121-12   .403-03
     .50   40.00    4.00    80.00  .105+17  .782-13 .101-12   .338-03
     .50   40.00    8.00    80.00  .420+17  .174-13 .556-13   .185-03
    4.00    1.00     .05      .25  .164+13  .182-09 .194-09   .645+00
    4.00    1.00     .10      .25  .657+13  .125-09 .162-09   .540+00
    4.00    1.00     .20      .25  .263+14  .279-10 .891-10   .297+00
    4.00    8.00     .40     2.00  .105+15  .285-11 .303-11   .101-01
    4.00    8.00     .80     2.00  .420+15  .196-11 .253-11   .845-02
    4.00    8.00    1.60     2.00  .168+16  .437-12 .139-11   .464-02
    4.00   40.00    2.00    10.00  .263+16  .114-12 .121-12   .404-03
    4.00   40.00    4.00    10.00  .105+17  .783-13 .101-12   .338-03
    4.00   40.00    8.00    10.00  .420+17  .175-13 .557-13   .186-03
   24.00    1.00     .05      .04  .164+13  .182-09 .194-09   .645+00
   24.00    1.00     .10      .04  .657+13  .125-09 .162-09   .540+00
   24.00    1.00     .20      .04  .263+14  .279-10 .890-10   .297+00
   24.00    8.00     .40      .33  .105+15  .284-11 .303-11   .101-01
   24.00    8.00     .80      .33  .420+15  .195-11 .253-11   .844-02
   24.00    8.00    1.60      .33  .168+16  .436-12 .139-11   .464-02
   24.00   40.00    2.00     1.67  .263+16  .114-12 .121-12   .404-03
   24.00   40.00    4.00     1.67  .105+17  .782-13 .101-12   .338-03
   24.00   40.00    8.00     1.67  .420+17  .175-13 .557-13   .186-03
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RADIONUCLIDE   SM 153
HALF LIFE   .195+01 DAYS
TOTAL RELEASE  .660-01 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .300-09 GRAMS PER CC
MAXIMUM PERMISSIBLE
                                                    .150-06     .160+05

 CURRENT     DOWN  RADIUS     TIME    VOLUME    CONCENTRATION AVE.SPEC.
VELOCITY CURRENT
  NM/DAY      NM      NM                              150-    AVE.  ACTIVITY
                               DAYS        CC    UCI/CC  UCI/CC    UCI/GM
     .50    1.00     .05     2.00  .164+13  .218-08 .232-08   .772+01
     .50    1.00     .10     2.00  .657+13  .150-08 .194-08   .696+01
     .50    1.00     .20     2.00  .263+14  .334-09 .107-08   .355+01
     .50    8.00     .40    16.00  .105+15  .235-12 .250-12   .833-03
     .50    8.00     .80    16.00  .420+15  .161-12 .209-12   .697-03
     .50    8.00    1.60    16.00  .168+16  .360-13 .115-12   .383-03
     .50   40.00    2.00    80.00  .263+16  .125-23 .132-23   .441-14
     .50   40.00    4.00    80.00  .105+17  .856-24 .111-23   .370-14
     .50   40.00    8.00    80.00  .420+17  .191-24 .609-24   .203-14
    4.00    1.00     .05      .25  .164+13  .406-08 .431-08   .144+02
    4.00    1.00     .10      .25  .657+13  .279-08 .361-08   .120+02
    4.00    1.00     .20      .25  .263+14  .622-09 .198-08   .661+01
    4.00    8.00     .40     2.00  .105+15  .340-10 .367-10   .121+00
    4.00    8.00     .80     2.00  .420+15  .234-10 .303-10   .101+00
    4.00    8.00    1.60     2.00  .168+16  .522-11 .166-10   .555-01
    4.00   40.00    2.00    10.00  .263+16  .793-13 .843-13   .281-03
    4.00   40.00    4.00    10.00  .105+17  .545-13 .706-13   .235-03
    4.00   40.00    8.00    10.00  .420+17  .122-13 .388-13   .129-03
   24.00    1.00     .05      .04  .164+13  .437-08 .465-08   .155+02
   24.00    1.00     .10      .04  .657+13  .300-08 .389-08   .130+02
   24.00    1.00     .20      .04  .263+14  .670-09 .214-08   .712+01
   24.00    8.00     .40      .33  .105+15  .615-10 .654-10   .218+00
   24.00    8.00     .80      .33  .420+15  .423-10 .548-10   .183+00
   24.00    8.00    1.60      .33  .168+16  .443-11 .301-10   .100+00
   24.00   40.00    2.00     1.67  .263+16  .153-11 .163-11   .543-02
   24.00   40.00    4.00     1.67  .105+17  .105-11 .136-11   .455-02
   24.00   40.00    8.00     1.67  .420+17  .235-12 .750-12   .250-02
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Down-current Distribution, BREACH-OF-CONTAINMENT Accident, Batch Release

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RADIONUCLIDE   EU 155
HALF LIFE   .661+03 DAYS
TOTAL RELEASE  .329-02 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .300-09 GRAMS PER CC
MAXIMUM PERMISSIBLE                                .380-06     .270+03

 CURRENT    DOWN  RADIUS     TIME    VOLUME   CONCENTRATION AVE.SPEC.
VELOCITY CURRENT                                  ISO-    AVE.  ACTIVITY
  NM/DAY      NM      NM     DAYS        CC   UCI/CC  UCI/CC    UCI/GM
     .50    1.00     .05     2.00   .164+13  .220-09 .235-09   .782+00
     .50    1.00     .10     2.00   .657+13  .152-09 .196-09   .655+00
     .50    1.00     .20     2.00   .263+14  .338-10 .108-09   .360+00
     .50    8.00     .40    16.00   .105+15  .339-11 .361-11   .120-01
     .50    8.00     .80    16.00   .420+15  .233-11 .302-11   .101-01
     .50    8.00    1.60    16.00   .168+16  .521-12 .166-11   .554-02
     .50   40.00    2.00    80.00   .263+16  .127-12 .135-12   .450-03
     .50   40.00    4.00    80.00   .105+17  .873-13 .113-12   .377-03
     .50   40.00    8.00    80.00   .420+17  .195-13 .621-13   .207-03
    4.00    1.00     .05      .25   .164+13  .221-09 .235-09   .783+00
    4.00    1.00     .10      .25   .657+13  .152-09 .197-09   .656+00
    4.00    1.00     .20      .25   .263+14  .339-10 .108-09   .360+00
    4.00    8.00     .40     2.00   .105+15  .345-11 .366-11   .122-01
    4.00    8.00     .80     2.00   .420+15  .237-11 .307-11   .102-01
    4.00    8.00    1.60     2.00   .168+16  .528-12 .169-11   .562-02
    4.00   40.00    2.00    10.00   .263+16  .137-12 .145-12   .485-03
    4.00   40.00    4.00    10.00   .105+17  .939-13 .122-12   .406-03
    4.00   40.00    8.00    10.00   .420+17  .210-13 .669-13   .223-03
   24.00    1.00     .05      .04   .164+13  .221-09 .235-09   .783+00
   24.00    1.00     .10      .04   .657+13  .152-09 .197-09   .656+00
   24.00    1.00     .20      .04   .263+14  .339-10 .108-09   .360+00
   24.00    8.00     .40      .33   .105+15  .345-11 .367-11   .122-01
   24.00    8.00     .80      .33   .420+15  .237-11 .307-11   .102-01
   24.00    8.00    1.60      .33   .168+16  .529-12 .169-11   .563-02
   24.00   40.00    2.00     1.67   .263+16  .138-12 .147-12   .489-03
   24.00   40.00    4.00     1.67   .105+17  .947-13 .123-12   .409-03
   24.00   40.00    8.00     1.67   .420+17  .211-13 .674-13   .225-03
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RADIONUCLIDE   EU 156
HALF LIFE   .154+02 DAYS
TOTAL RELEASE  .585-02 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .300-09 GRAMS PER CC
MAXIMUM PERMISSIBLE                                .000        .000

 CURRENT    DOWN  RADIUS     TIME    VOLUME   CONCENTRATION AVE.SPEC.
VELOCITY CURRENT                                  ISO-    AVE.  ACTIVITY
  NM/DAY      NM      NM     DAYS        CC   UCI/CC  UCI/CC    UCI/GM
     .50    1.00     .05     2.00   .164+13  .359-09 .382-09   .127+01
     .50    1.00     .10     2.00   .657+13  .247-09 .320-09   .107+01
     .50    1.00     .20     2.00   .263+14  .551-10 .176-09   .586+00
     .50    8.00     .40    16.00   .105+15  .299-11 .318-11   .106-01
     .50    8.00     .80    16.00   .420+15  .205-11 .266-11   .887-02
     .50    8.00    1.60    16.00   .168+16  .458-12 .146-11   .487-02
     .50   40.00    2.00    80.00   .263+16  .671-14 .714-14   .238-04
     .50   40.00    4.00    80.00   .105+17  .461-14 .597-14   .199-04
     .50   40.00    8.00    80.00   .420+17  .103-14 .328-14   .109-04
    4.00    1.00     .05      .25   .164+13  .388-09 .413-09   .138+01
    4.00    1.00     .10      .25   .657+13  .267-09 .346-09   .115+01
    4.00    1.00     .20      .25   .263+14  .596-10 .190-09   .634+00
    4.00    8.00     .40     2.00   .105+15  .561-11 .597-11   .199-01
    4.00    8.00     .80     2.00   .420+15  .386-11 .500-11   .167-01
    4.00    8.00    1.60     2.00   .168+16  .860-12 .274-11   .915-02
    4.00   40.00    2.00    10.00   .263+16  .157-12 .167-12   .555-03
    4.00   40.00    4.00    10.00   .105+17  .108-12 .139-12   .465-03
    4.00   40.00    8.00    10.00   .420+17  .240-13 .766-13   .255-03
   24.00    1.00     .05      .04   .164+13  .392-09 .417-09   .139+01
   24.00    1.00     .10      .04   .657+13  .270-09 .349-09   .116+01
   24.00    1.00     .20      .04   .263+14  .601-10 .192-09   .640+00
   24.00    8.00     .40      .33   .105+15  .605-11 .643-11   .214-01
   24.00    8.00     .80      .33   .420+15  .416-11 .539-11   .180-01
   24.00    8.00    1.60      .33   .168+16  .927-12 .296-11   .986-02
   24.00   40.00    2.00     1.67   .263+16  .228-12 .242-12   .808-03
   24.00   40.00    4.00     1.67   .105+17  .157-12 .203-12   .676-03
   24.00   40.00    8.00     1.67   .420+17  .349-13 .111-12   .372-03
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Down-current Distribution, BREACH-OF-CONTAINMENT Accident, Batch Release

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RADIONUCLIDE   EU 157
HALF LIFE   .629+00 DAYS
TOTAL RELEASE  .126-02 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .300-09 GRAMS PER CC
MAXIMUM PERMISSIBLE                                 .000        .000

 CURRENT     DOWN   RADIUS     TIME    VOLUME    CONCENTRATION AVE.SPEC.
VELOCITY CURRENT                                  ISO-   AVE.  ACTIVITY
  NM/DAY      NM       NM     DAYS         CC   UCI/CC  UCI/CC   UCI/GM
     .50    1.00      .05     2.00   .164+13  .934-11 .994-11  .331-01
     .50    1.00      .10     2.00   .657+13  .642-11 .832-11  .277-01
     .50    1.00      .20     2.00   .263+14  .143-11 .457-11  .152-01
     .50    8.00      .40    16.00   .105+15  .292-19 .311-19  .104-09
     .50    8.00      .80    16.00   .420+15  .201-19 .260-19  .867-10
     .50    8.00     1.60    16.00   .168+16  .448-20 .143-19  .476-10
     .50   40.00     2.00    80.00   .263+16  .000    .000     .000
     .50   40.00     4.00    80.00   .105+17  .000    .000     .000
     .50   40.00     8.00    80.00   .420+17  .000    .000     .000
    4.00    1.00      .05      .25   .164+13  .642-10 .683-10  .228+00
    4.00    1.00      .10      .25   .657+13  .442-10 .572-10  .191+00
    4.00    1.00      .20      .25   .263+14  .985-11 .314-10  .105+00
    4.00    8.00      .40     2.00   .105+15  .146-12 .155-12  .518-03
    4.00    8.00      .80     2.00   .420+15  .100-12 .130-12  .433-03
    4.00    8.00     1.60     2.00   .168+16  .224-13 .714-13  .238-03
    4.00   40.00     2.00    10.00   .263+16  .868-18 .923-18  .308-08
    4.00   40.00     4.00    10.00   .105+17  .597-18 .773-18  .258-08
    4.00   40.00     8.00    10.00   .420+17  .133-18 .425-18  .142-08
   24.00    1.00      .05      .04   .164+13  .808-10 .860-10  .287+00
   24.00    1.00      .10      .04   .657+13  .555-10 .720-10  .240+00
   24.00    1.00      .20      .04   .263+14  .124-10 .395-10  .132+00
   24.00    8.00      .40      .33   .105+15  .916-12 .974-12  .325-02
   24.00    8.00      .80      .33   .420+15  .629-12 .816-12  .272-02
   24.00    8.00     1.60      .33   .168+16  .140-12 .448-12  .149-02
   24.00   40.00     2.00     1.67   .263+16  .843-14 .897-14  .299-04
   24.00   40.00     4.00     1.67   .105+17  .579-14 .751-14  .250-04
   24.00   40.00     8.00     1.67   .420+17  .129-14 .412-14  .137-04
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RADIONUCLIDE   GD 159
HALF LIFE   .750+00 DAYS
TOTAL RELEASE  .224-03 CURIES
NATURAL CONCENTRATION OF CARRIER IN SEAWATER  .300-09 GRAMS PER CC
MAXIMUM PERMISSIBLE                                .150-06      .240+05

 CURRENT     DOWN   RADIUS     TIME    VOLUME    CONCENTRATION AVE.SPEC.
VELOCITY CURRENT                                  ISO-   AVE.  ACTIVITY
  NM/DAY      NM       NM     DAYS         CC   UCI/CC  UCI/CC   UCI/GM
     .50    1.00      .05     2.00   .164+13  .237-11 .252-11  .840-02
     .50    1.00      .10     2.00   .657+13  .163-11 .211-11  .704-02
     .50    1.00      .20     2.00   .263+14  .363-12 .116-11  .387-02
     .50    8.00      .40    16.00   .105+15  .892-19 .949-19   316-09
     .50    8.00      .80    16.00   .420+15  .613-19 .795-19  .265-09
     .50    8.00     1.60    16.00   .168+16  .137-19 .437-19  .146-09
     .50   40.00     2.00    80.00   .263+16  .000    .000     .000
     .50   40.00     4.00    80.00   .105+17  .000    .000     .000
     .50   40.00     8.00    80.00   .420+17  .000    .000     .000
    4.00    1.00      .05      .25   .164+13  .119-10 .127-10  .423-01
    4.00    1.00      .10      .25   .657+13  .821-11 .106-10  .354-01
    4.00    1.00      .20      .25   .263+14  .183-11 .584-11  .195-01
    4.00    8.00      .40     2.00   .105+15  .370-13 .394-13  .131-03
    4.00    8.00      .80     2.00   .420+15  .255-13 .330-13  .110-03
    4.00    8.00     1.60     2.00   .168+16  .568-14 .181-13  .604-04
    4.00   40.00     2.00    10.00   .263+16  .913-18 .971-18  .324-08
    4.00   40.00     4.00    10.00   .105+17  .627-18 .813-18  .271-08
    4.00   40.00     8.00    10.00   .420+17  .140-18 .447-18  .149-08
   24.00    1.00      .05      .04   .164+13  .145-10 .154-10  .513-01
   24.00    1.00      .10      .04   .657+13  .995-11 .129-10  .430-01
   24.00    1.00      .20      .04   .263+14  .222-11 .708-11  .236-01
   24.00    8.00      .40      .33   .105+15  .173-12 .184-12  .613-03
   24.00    8.00      .80      .33   .420+15  .119-12 .159-12  .513-03
   24.00    8.00     1.60      .33   .168+16  .265-13 .845-13  .282-03
   24.00   40.00     2.00     1.67   .263+16  .202-14 .214-14  .715-05
   24.00   40.00     4.00     1.67   .105+17  .139-14 .180-14  .598-05
   24.00   40.00     8.00     1.67   .420+17  .309-15 .986-15  .329-05
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